APOLLO MISSIONS

HOW NASA TOOK US TO THE MOON

APOLLO
11
AS IT HAPPENED

FROM THE MAKERS OF All About Space

Digital Edition

SIXTH EDITION

HEROIC CREWS • DARING LAUNCHES • INCREDIBLE DISCOVERIES

All About Space

Welcome to the APOLLO MISSIONS

"That's one small step for a man, one giant leap for mankind…"
On 20 July 1969, Neil Armstrong made the historic first steps on the Moon. This special edition celebrates the innovative program that made one of humanity's greatest achievements possible.

Project Apollo was a shining example of what can be achieved when humanity works towards a common goal. In less than ten years, the initiative developed the technologies and spacecraft that would take humans to the Moon. Discover the missions that paved the way for Apollo 11's historic journey, the astronauts who followed in Neil Armstrong's first footsteps, and the brave crews that risked their lives in the name of exploration and space science.

Beyond the Moon missions, Apollo technologies were instrumental in launching and maintaining the International Space Station. With NASA now setting its sights on sending astronauts back to the Moon in the next few years, Apollo's legacy is alive and well.

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THE APOLLO ERA

How NASA put man on the Moon in less than a decade

*Dates in headings are mission launch dates unless otherwise stated

1961-1966

SA and AS unmanned missions

In preparation for the manned Moon missions, NASA conducted a series of tests using various iterations of the Saturn rocket, in order to practice launch, Low Earth Orbit, re-entry and mission aborts.

July-August 1966

AS-202 and AS-203 (unofficially Apollo 2 and 3, re-designated)

- Unmanned
- Test flights, success

After AS-204's launch test disaster, the mission was retroactively renamed Apollo 1 and the names of future missions were changed. Apollo 2 (which was due to be a repeat of Apollo 1) and Apollo 3 (due to be the first test of the Block II CSM) were re-designated as the earlier 1966 test flights AS-202 and AS-203 respectively, but they were not officially renumbered in the Apollo series.

27 January 1967

Apollo 1 (AS-204)

- Test flight, never launched
- See page 40

Destroyed during a pre-flight test when a fire in the Command Module tragically killed the crew.

9 November 1967

Apollo 4

- Unmanned
- Test flight, success

The next Apollo mission in the programme, a Type-A unmanned flight, was the first test of the Saturn V rocket that would eventually take man to the Moon.

22 January 1968

Apollo 5

- Unmanned
- Test flight, success

The next unmanned mission was a Type-B on a Saturn IB rocket and marked the first flight of the Lunar Module, including successful tests of its ascent and descent engines, and a simulation of a landing abort.

4 April 1968

Apollo 6

- Unmanned
- Test flight, engine failure

The final unmanned Apollo mission was used to test the Saturn V's ability to propel the spacecraft into trans-lunar injection (TLI). The flight experienced problems from the start, including a vibration problem that damaged the fuel lines.

11 October 1968

Apollo 7

- Earth orbit, success
- See page 52

The first manned test flight of the Apollo Block II Command and Service Module (CSM).

21 December 1968

Apollo 8

- Lunar orbit, success
- See page 58

The first humans to fly to the Moon, and the first manned Saturn V flight.

3 March 1969

Apollo 9

- Earth orbit, success
- See page 66

First orbital tests of the Lunar Module, including separation and docking.

18 May 1969

Apollo 10

- Lunar orbit, success
- See page 72

The 'dress rehearsal' for the Moon landing, testing all procedures besides the landing itself.

16 July 1969

Apollo 11

- Lunar landing, success
- See page 80

The historic lunar landing. Neil Armstrong became the first person to set foot on another world.

14 November 1969

Apollo 12

- Lunar landing, success
- See page 92

After surviving lightning during launch, Apollo 12 successfully landed on the Moon at the aptly named Ocean of Storms.

11 April 1970

Apollo 13

- Lunar landing, aborted on outbound flight
- See page 98

An oxygen tank explosion forced the crew to make critical repairs and abort their mission.

31 January 1971

Apollo 14

- Lunar landing, success
- See page 106

The first visit to lunar highlands. Commander Alan Shepard famously played golf on the Moon with a makeshift club.

26 July 1971

Apollo 15

- Lunar exploration, success
- See page 112

First use of the Lunar Roving Vehicle to cover greater areas of the Moon during each EVA.

16 April 1972

Apollo 16

- Lunar exploration, success
- See page 120

The second mission to the lunar highlands collected nearly 100kg (220lb) of lunar samples.

7 December 1972

Apollo 17

- Lunar exploration, success
- See page 126

The final Apollo mission remains the last time humans visited the Moon, or even left low-Earth orbit.

Launching Project Apollo

10 Apollo's origins

18 Shooting for the Moon: astronaut selection and training

22 Hall of fame

26 The Apollo spacesuit

28 Saturn V

30 Inside the Apollo spacecraft

USA

To beat the Soviet Union to the surface of the Moon, America needed something big. Project Apollo was the answer

THE ORIGINS OF APOLLO

Reported by Jonathan O'Callaghan

"…Now it is time to take longer strides, time for a great new American enterprise, time for this nation to take a clearly leading role in space achievement, which in many ways may hold the key to our future on earth.

I believe we possess all the resources and talents necessary. But the facts of the matter are that we have never made the national decisions or marshalled the national resources required for such leadership. We have never specified long-range goals on an urgent time schedule, or managed our resources and our time so as to ensure their fulfilment.

[…] Space is open to us now; and our eagerness to share its meaning is not governed by the efforts of others. We go into space because whatever mankind must undertake, free men must fully share.

I therefore ask the Congress, above and beyond the increases I have earlier requested for space activities, to provide the funds which are needed to meet the following national goals:

First, I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth. No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space; and none will be so difficult or expensive to accomplish. We propose to accelerate the development of the appropriate lunar space craft. We propose to develop alternate liquid and solid fuel boosters, much larger than any now being developed, until certain which is superior. We propose additional funds for other engine development and for unmanned explorations, explorations which are particularly important for one purpose which this nation will never overlook: the survival of the man who first makes this daring flight. But in a very real sense, it will not be one man going to the moon; if we make this judgment affirmatively, it will be an entire nation. For all of us must work to put him there."

Kennedy's speech to Congress

On 25 May 1961 in a speech to Congress on "Urgent National Needs", President Kennedy stated his belief that the US should endeavour to land humans on the Moon by the end of the decade, beating the Soviets to the ultimate prize in the process. Across the nation, his speech was met with huge amounts of support, with little concern given to the risk or cost of such a programme. It was a pivotal moment in drumming up support for the lunar missions and made many believe such an effort was possible.

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The Soviet Union stunned the world on 4 October 1957 when it announced that it had launched a satellite into orbit for the first time, Sputnik 1. The United States of America, which was finding itself rapidly locked in a Cold War battle with the Soviet Union to prove their technological prowess, had been dealt a blow. The Soviets, clearly, had a superior space programme, and while it was claimed to be for peaceful purposes, the comparisons to launching missiles were plain to see.

Thus in 1960, a Senator for Massachusetts called John F Kennedy ran for president as a Democrat with a notable slogan: "Let's get this country moving again." One of Kennedy's key aims was to prove that the US was every bit as capable as its Soviet counterparts, if not more so, and that included becoming a major force in the growing space arena. Kennedy was ultimately elected in November 1960, following a closely fought battle between himself and Republican Richard Nixon. And immediately, he set to work surpassing the achievements of his predecessor, the Republican Dwight D Eisenhower.

While Kennedy had little interest in space, he understood the importance of it on a global scale. He had appointed Jerome B Wiesner of the Massachusetts Institute of Technology to advise him on space matters, and Wiesner suggested that leadership in space would be a matter of 'national prestige', and the US had to take on the Soviets.

Below: NASA's Ed White performing a spacewalk during the Gemini 4 mission on 3 June 1965

Top right: The first successful Apollo crew, that of Apollo 7 (pictured), launched on 22 May 1968

Lower right: Christopher Kraft, flight director during Project Mercury, at his station in Mission Control

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SCHIRRA
NASA

© NASA (public domain)

This was not just for military purposes, but for civilian purposes too – including monitoring Earth's weather, sending communications across the globe, and more.

America's space programme, however, was lacklustre. Its formal space agency, the National Aeronautics and Space Administration (NASA), had only been established in July 1958 as a response to the Soviet launch of Sputnik 1. Wiesner argued that NASA should focus more on scientific endeavours than human spaceflight, which the Soviets were rumoured to be working towards, but Kennedy was more interested in the human aspect. Kennedy actually initially touted the possibility of working with the Soviets on human spaceflight in a speech in January 1961. The Soviets, however, did not seem keen to play ball.

NASA was already in the process of training seven astronauts for the first American human spaceflights, as part of a programme called Project Mercury. Progress was gradual however, with plans to launch humans for the first time in the mid-1960s. In March 1961 however, then NASA administrator James E Webb asked Kennedy for a bigger budget to attempt landing humans on the Moon by the end of the decade, a project called Apollo, and something the Soviets were also known to be working towards. Kennedy refused, giving Webb instead a modest budget increase. Then, everything changed.

On 12 April 1961, the Soviets shocked the world once again by launching Yuri Gagarin into orbit, the first human ever to reach space. Gagarin became a hero around the world, promoting the Soviet Union and its technological prowess to no end in the process. In the midst of the Cold War, and a battle between two superpowers for control of the world, the Soviets had gained a clear advantage. NASA would follow suit just weeks later with Alan Shepard's flight to space on 5 May 1961, but the first blow had been struck. The Soviet Union, it seemed, had the edge on their American counterparts.

SEAL OF THE PRESIDENT OF THE UNITED STATES

"We set sail on this new sea because there is new knowledge to be gained, and new rights to be won, and they must be won and used for the progress of all people. For space science, like nuclear science and all technology, has no conscience of its own.

[…] There is no strife, no prejudice, no national conflict in outer space as yet. Its hazards are hostile to us all. Its conquest deserves the best of all mankind, and its opportunity for peaceful cooperation many never come again. But why, some say, the moon? Why choose this as our goal? And they may well ask why climb the highest mountain? Why, 35 years ago, fly the Atlantic? Why does Rice play Texas?

We choose to go to the moon. We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win, and the others, too.

It is for these reasons that I regard the decision last year to shift our efforts in space from low to high gear as among the most important decisions that will be made during my incumbency in the office of the Presidency.

[…] Many years ago the great British explorer George Mallory, who was to die on Mount Everest, was asked why did he want to climb it. He said, "Because it is there."

Well, space is there, and we're going to climb it, and the moon and the planets are there, and new hopes for knowledge and peace are there. And, therefore, as we set sail we ask God's blessing on the most hazardous and dangerous and greatest adventure on which man has ever embarked."

Kennedy's speech to Congress

On 25 May 1961 in a speech to Congress on "Urgent National Needs", President Kennedy stated his belief that the US should endeavour to land humans on the Moon by the end of the decade, beating the Soviets to the ultimate prize in the process. Across the nation, his speech was met with huge amounts of support, with little concern given to the risk or cost of such a programme. It was a pivotal moment in drumming up support for the lunar missions and made many believe such an effort was possible.

> “While Gagarin had orbited Earth in his Vostok 1 spacecraft, Shepard had only briefly entered space”

Left: America’s efforts to land on the Moon were ultimately successful

Below: Ham the chimpanzee, one of several animal astronauts that NASA trained in preparation for manned missions

Below left: Many astronauts from Project Mercury (pictured) and Project Gemini later flew on Apollo missions

The road to Apollo

1958

Founding of NASA

29 July 1958

The National Aeronautics and Space Administration (NASA) is established, a first true national space programme for the US.

1960

JFK elected

8 November 1960

John F Kennedy is elected as the 35 President of the United States after a narrow victory against Richard Nixon.

1961

First American in space

5 May 1961

Alan Shepard becomes the first American to reach space, weeks after Soviet Yuri Gagarin became the first human.

1961

Speech to Congress

25 May 1961

Kennedy tells Congress of his proposal to land humans on the Moon by the end of the decade.

1962

“We choose to go to the Moon”

12 September 1962

Kennedy gives an impassioned and historic speech on why America should reach for the Moon at Rice University in Texas.

Not helping matters was the nature of the two missions. While Gagarin had orbited Earth in his Vostok 1 spacecraft, a flight that lasted 108 minutes, Shepard had only briefly entered space on a looping suborbital path, with a total flight time of just 15 minutes. Not only was America second to reach space after the Soviet Union, but its technology was also clearly inferior. Things got worse in April 1961 with the disastrous Bay of Pigs invasion in Cuba, a failed effort to overthrow the communist leader Fidel Castro.

As a result of both of these events, Kennedy took note. He re-examined Webb's proposal for reaching the Moon, and while the cost of $20 billion was deemed too high, his interest was piqued. In April 1961, he asked Lyndon B Johnson, who was the head of the National Aeronautics and Space Council that advised the White House on space matters, whether the US had any chance of beating the Soviets to the Moon. Was it a race worth entering?

By the end of April, Johnson returned to Kennedy with a report. Hugh Dryden, who was the Deputy Administrator of NASA, had told him it was possible the US could launch humans to the Moon with "a determined national effort" by 1967 at a cost of $33 billion. Wernher von Braun, a German engineer that had emigrated to the US at the conclusion of the Second World War, said there as a "sporting chance" of sending three people around the Moon before the Soviets, and an "excellent chance" of beating them to the surface. He also suggested a landing as soon as 1967 was possible.

Johnson, as part of his investigation, came up with an ambitious programme of space exploration that would culminate in a lunar landing. It would include NASA's Project Mercury, which was already in production, and also the later-devised Project Gemini. These projects would involve increasingly daring flights of humans into space, testing some key technologies along the way. Americans would have to prove they could not only survive in space but also dock spacecraft, perform tasks, and much more. Mercury missions would see single humans at a time travel into space, but the Gemini missions would be capable of carrying two humans into orbit. Ultimately, Apollo was designed to carry three. Kennedy approved of the proposal, and gave a speech at Congress on 25 May 1961 that inspired the public to dream of what might be possible.

An attempt at a lunar landing would be a shining beacon of US technological prowess. It would demonstrate their capabilities in space, it would be arguably the biggest moment in the history of mankind, and most importantly, it would set the US as the world's leading superpower ahead of the Soviet Union. Kennedy's speech at Rice University in Texas on 12 September 1962 was the crowning moment of a nation wrapped up in the thrilling efforts to send humans to the Moon, as he re-emphasised the importance of America reaching the lunar surface first. The US would go on to spend $20 billion on the Apollo programme, a figure of more than $100 billion today when adjusted for inflation.

Ultimately, of course, Kennedy's desire came to fruition. Despite setbacks and tragedies, the US did indeed reach the surface of the Moon just five months before the conclusion of the decade. All thanks to a tiny satellite, Sputnik 1, and a plucky Soviet hero, Yuri Gagarin, the US space programme was inspired to excel to new heights, becoming the pre-eminent space programme in the world, a position that it still undoubtedly holds today.

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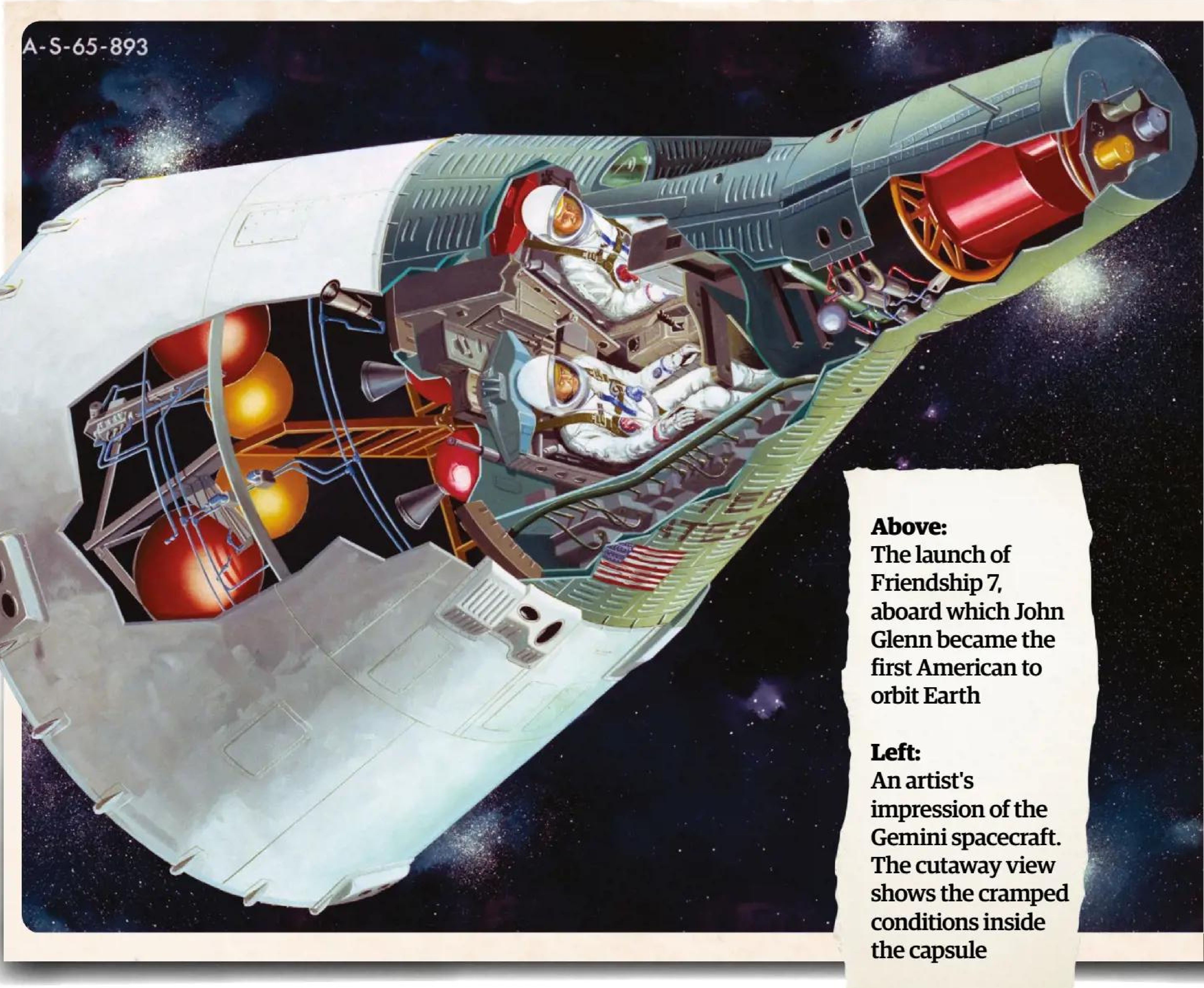

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Above:
The launch of Friendship 7, aboard which John Glenn became the first American to orbit Earth

Left:
An artist's impression of the Gemini spacecraft. The cutaway view shows the cramped conditions inside the capsule

1965

First spacewalk
18 March 1965
Alexei Leonov becomes the first person to perform a spacewalk, another major first for the Soviet Union.

1965

Americans in orbit
23 March 1965
Gus Grissom and John Young become the first Americans to orbit Earth on the first crewed Gemini mission.

1968

Apollo rises
11 October 1968
Apollo 7 launches from Cape Kennedy (now Cape Canaveral) in Florida, the first crewed spacecraft of Project Apollo.

1969

The Soviets falter
21 February 1969
The N1 rocket, meant to be the Soviet Union's answer to the Saturn V, fails on its first launch.

1969

Lunar landing
20 July 1969
Apollo 11 lands on the Moon, fulfilling the goal of reaching the Moon by the end of the decade.

From battling river rapids and weathering sandstorms to scaling walls and flying spacecraft propelled at eye-watering speeds, preparing to be the first on the lunar surface wasn't for the faint-hearted

SHOOTING FOR THE MOON

How NASA trained its Apollo astronauts

Reported by Gemma Lavender

© NASA; SpoonGraphics

Main: Apollo 11's Neil Armstrong and Buzz Aldrin are given instructions before Extravehicular Activity (EVA) training

Centre: Underwater training gives astronauts a similar experience to working in micro-gravity

Right: Apollo astronauts underwent weightlessness training. Here. Edwin 'Buzz' Aldrin is aboard a KC-135 aircraft

Lower right: Apollo 11 astronauts Neil Armstrong and Buzz Aldrin train on a fake lunar surface ahead of the historic lunar landing

"We choose to go to the Moon in this decade and do the other things, not because they are easy, but because they are hard," the 35th President of the United States John F. Kennedy said resolutely to a large crowd that had gathered around his podium at Rice University Stadium in Houston, Texas, on 12 September 1962. That day, the politician had laid down a gauntlet to NASA. The space agency's job was to find the astronauts with the right stuff. Fortunately for them, they weren't short of those wanting to step up to the challenge.

One of the first candidates came in the form of a six-foot former pilot of the US Navy. An individual who had seen action in the Korean War, flying 78 missions for a total of 121 hours, later becoming an experimental research test pilot. He went by the name of Neil Armstrong.

To NASA, Armstrong was the perfect fit; the space agency had decided that some experience of flying jets was indeed much more valuable than any kind of scientific training. Plus, there were time constraints, which meant that the team who would later land on the Moon in July 1969 would need to come well-equipped with experience. Naturally, NASA looked to the Navy and Air Force to make their selections, but it turned out that Armstrong – who was chosen as a candidate in 1962 – became the only successful civilian candidate. His future crewmates Edwin 'Buzz' Aldrin and Michael Collins would be selected the following year, fresh from the Air Force and raring to go, their flight capability backed up with degrees in aeronautical engineering and science.

At the time of selection, only a mere nine men had been to the Moon as part of Apollo 8, Apollo 9 and Apollo 10. Their aim was to swing into lunar orbit and test every aspect of hardware that would make future missions possible. When it came to training, the tasks laid out before Armstrong, Aldrin and Collins were no different: every day, hour, minute and second was a dress rehearsal in how to get to make that "one small step for [a] man, one giant leap for mankind" a reality. There was lots to do; NASA hadn't flown more than one astronaut at any one time, especially not for a stretch of eight days, and its astronauts certainly hadn't left a craft during a mission. What's more, the agency hadn't begun testing what's involved in docking two spacecraft as they whizzed around the Earth at eight kilometres (five miles) per second. There was an enormous amount to play for.

The Apollo astronauts worked tirelessly for 16 hours on a daily basis. No stone was left unturned in simulating the spacecraft, conditions or environment the spacefarers would face – what's more, there were fewer computers and technologies than those easily available at our fingertips today.

UNITED STATES

That means, if you took a walk through the testing facilities at NASA back in the 1960s, they'd look quite primitive. If the space agency wanted to reduce gravity to the one-sixth you'd discover on the Moon, they suspended their candidates on a steeply-inclined wall; making them run, jump and walk along it. A far cry from today's jetliners that swoop in arcs, giving passengers the low gravity experience for minutes at a time.

Despite the obvious restraints, the facilities looked the part. An Apollo lander, fashioned out of aluminium and with over 1,800 kilograms (4,000 pounds) of thrust generated by an electric engine was born out of a collaboration between NASA and Bell Aerosystems. Surrounding it, fake Moonrocks littered the surface to accurately depict the landing site. Everything was accounted for; from Armstrong's attempts at piloting in preparation for the nail-biting, bumpy descent to the cratered, mountainous terrain, to the planting of the US flag. Armstrong, given that he would be the Commander of Apollo 11, had to practice his first step onto an 'alien surface' and climb back onto the lunar lander to mock up the return home. "I really don't have the foggiest idea of what I was doing," a puzzled Armstrong was quoted as saying after the simulation. "If I were simulating a mission phase, I would have the helmet on and suit pressurised."

The primary aim of Apollo 11 was to not only observe the Moon, but to collect samples of it for further analysis. For this part of the programme, both Armstrong and Buzz Aldrin were led out to the Arizona desert. It's here that NASA and scientists from America's Geological Survey, or USGS for short, had been blasting large craters into the dry surface; a perfect representation of the lunar terrain as the pair of astronauts discovered on their tour of the arid location, the USGS taught them about geological features as they explored. On what seemed to be the perfect site, simulations and soil sampling techniques were practiced with the astronauts donning replica spacesuits to create an authentic experience. Future Apollo astronauts, namely James Irwin and Dave Scott of Apollo 15, returned here later to test out the first lunar rover.

Getting the lunar surface was just as important as the return home. It was intended that the astronauts would make a splashdown in the ocean. But what if the capsule missed its mark? According to NASA, there was every chance that the trio could have crash landed thousands of miles off course, smashing through the leafy, warm and wet greenery of a jungle or smacking and sinking into the sands of a sweltering, hot desert. Wherever they ended up, they had to be prepared to survive the environmental extremes.

For such an occasion, the astronauts were packed up and carted off to the Panama Jungle Survival School located at Albrook Air Force Base, where they were tasked with anything from chopping down trees and foraging for food, to making the most of leaves and branches to create lean-tos, and tackling the challenging river rapids of the Panama Canal Zone. If the astronauts were extremely unlucky, they'd land in the desert. The Stead Air Force Base in Nevada suited their needs perfectly for tackling these complexities, as it was ideal for desert survival training. Apollo astronauts, even beyond the days of Apollo 11 were experts at creating makeshift shelters to weather sandstorms and steering clear of any desert wildlife perceived to be dangerous.

On 20 July 1969, the relentless training Armstrong, Aldrin and Collins had endured might have been gruelling, but it had helped them to make history. From the lunar surface, Aldrin stopped carrying out his experiments and answered a call. It was President Nixon, congratulating him and Armstrong on a successful landing. "All of us look forward to seeing you on the USS Hornet on Thursday," Nixon closed. Aldrin replied, "I look forward to that very much, sir."

Apollo highlights: getting mission-ready

Planting flags and picking rocks

It was perhaps one of the most iconic moments of Apollo 11: Neil Armstrong planting the US flag into lunar soil. And he had to train for it in a simulated Moonscape surrounded by 'lunar rocks'. It was also common practice for all Apollo astronauts to play pretend when it came to collecting samples!

Stepping onto the lunar surface

It was one small step for [a] man, one giant leap for mankind. Apollo 11 Commander Neil Armstrong had to practice climbing up and down the ladder that led from the Lunar Module – dubbed Eagle – to the lunar surface repeatedly a week before he and his crew launched for the Moon.

Walking in reduced gravity

On the Moon, Apollo 11 astronauts experienced gravity that meant they 'weighed in' at one-sixth their weight. The best way to simulate the experience was for would-be spacefarers to move along a wall inside the hangar at NASA's Langley Research Center. It gave an insight into how fast astronauts would be able to move.

Splashdown!

It's a tried and tested method that has served astronauts well. The Apollo spacecraft were designed to return to our home planet by making an almighty splashdown into the Earth's extensive oceans. Knowing what to expect meant that astronauts had to train in pools of water, swimming around model space capsules.

Simulating the perfect landing

Featuring a General Electric turbofan engine, a vehicle that represented the Lunar Module was thrust into the air and could reach elevations of up to 450 metres (1,500 feet) to replicate the Moon's low gravity (one-sixth that of Earth's).

Apollo astronaut hall of fame

From Apollo 1 to Apollo 17, these pioneers of spaceflight have earned a place in the history books

By Baljeet Panesar

KEY:

Entered lunar orbit

Walked on Moon

JAMES 'JIM' LOVELL

b. 25 March 1928

- US Navy test pilot
- Gemini 7
- Gemini 12

APOLLO 8
COMMAND MODULE PILOT

APOLLO 13
COMMANDER

FRANK BORMAN

b. 14 March 1928

- US Air Force fighter pilot
- Aeronautical engineering Master's degree
- Gemini 7

APOLLO 8
COMMANDER

WILLIAM ANDERS

b. 17 October 1933

- Electrical engineering degree
- Nuclear engineering Master's degree
- US Air Force fighter pilot

APOLLO 8
LUNAR MODULE PILOT

JAMES MCDIVITT

b. 10 June 1929

- Aeronautical engineering degree
- US Air Force experimental flight test pilot
- Gemini 4

APOLLO 9
(EARTH ORBIT)
COMMANDER

DAVID SCOTT

b. 6 June 1932

- US Air Force test pilot
- Astronautics and Aeronautics Master's degree
- Gemini 8

APOLLO 9
(EARTH ORBIT)
COMMAND MODULE PILOT

APOLLO 15
COMMANDER

RUSSELL 'RUSTY' SCHWEICKART

b. 25 October 1935

- US Air Force fighter pilot
- Aeronautical engineering degree
- Aeronautics and Astronautics Master's degree

APOLLO 9
(EARTH ORBIT)
LUNAR MODULE PILOT

VIRGIL 'GUS' GRISSOM

3 April 1926 –
27 January 1967

- US Air Force test pilot
- Mercury-Redstone 4
- Gemini 3

APOLLO 1
COMMANDER

EDWARD 'ED' WHITE

14 November 1930 –
27 January 1967

- Aeronautical engineering Master's degree
- US Air Force test pilot
- Gemini 4

APOLLO 1
COMMAND PILOT

ROGER CHAFFEE

15 February 1935 –
27 January 1967

- Aeronautical engineering degree
- US Navy jet aircraft pilot
- Gemini 4 capsule communications specialist

APOLLO 1
PILOT

WALTER CUNNINGHAM

b. 16 March 1932

- US Marine Corps fighter pilot
- Physics Master's degree

APOLLO 7
(EARTH ORBIT)
LUNAR MODULE PILOT

DONN EISELE

23 June 1930 –
2 December 1987

- Astronautics Master's degree
- US Air Force test pilot

APOLLO 7
(EARTH ORBIT)
COMMAND MODULE PILOT

WALTER 'WALLY' SCHIRRA

12 March 1923 –
3 May 2007

- US Navy test pilot
- Mercury-Atlas 8
- Gemini 6A

APOLLO 7
(EARTH ORBIT)
COMMANDER

THOMAS STAFFORD

b. 17 September 1930

- US Air Force test pilot
- Gemini 6A
- Gemini 9A

APOLLO 10
COMMANDER

EUGENE 'GENE' CERNAN

14 March 1934 –
16 January 2017

- Aeronautical engineering Master's degree
- US Navy fighter pilot
- Gemini 9A

APOLLO 10
LUNAR MODULE PILOT

APOLLO 17
COMMANDER

JOHN YOUNG

24 September 1930 –
5 January 2018

- US Navy test pilot
- Gemini 3
- Gemini 10

APOLLO 10
COMMAND MODULE PILOT

APOLLO 16
COMMANDER

NEIL ARMSTRONG

5 August 1930 – 25 August 2012

- Aerospace engineering Master's degree
- NASA research test pilot
- Gemini 8

APOLLO 11
COMMANDER

EDWIN 'BUZZ' ALDRIN

20 January 1930

- Astronautics doctorate
- US Air Force jet fighter pilot
- Gemini 12

APOLLO 11
LUNAR MODULE PILOT

MICHAEL COLLINS

31 October 1930

- US Air Force jet fighter pilot
- US Air Force test pilot
- Gemini 10

APOLLO 11
COMMAND MODULE PILOT

JAMES IRWIN

17 March 1930 – 8 August 1991

- Aeronautical engineering and instrumentation engineering Master's degree
- US Air Force test pilot

APOLLO 15
LUNAR MODULE PILOT

STUART ROOSA

16 August 1933 – 12 December 1994

- Aeronautical engineering degree
- US Air Force test pilot
- US Air Force fighter jet pilot

APOLLO 14
COMMAND MODULE PILOT

EDGAR MITCHELL

17 September 1930 – 4 February 2016

- Aeronautics degree
- US Naval aviator
- US Air Force test pilot

APOLLO 14
LUNAR MODULE PILOT

ALFRED 'AL' WORDEN

b. 7 February 1932

- Astronautical and Aeronautical engineering Master's degree
- US Air Force fighter pilot
- Member of astronaut support crew for Apollo 9 mission

APOLLO 15
COMMAND MODULE PILOT

CHARLES 'CHARLIE' DUKE

b. 3 October 1935

- Aeronautics and Astronautics Master's degree
- US Air Force jet fighter pilot

APOLLO 16
LUNAR MODULE PILOT

THOMAS KENNETH 'KEN' MATTINGLY

b. 17 March 1936

- Aeronautical engineering degree
- US Navy test pilot
- Original Command Module Pilot for Apollo 13 mission

APOLLO 16
COMMAND MODULE PILOT

CHARLES 'PETE' CONRAD

2 June 1930 –
8 July 19997

- US Navy jet fighter pilot
- Gemini 5
- Gemini 11

APOLLO 12
COMMANDER

ALAN BEAN

15 March 1932 –
26 May 2018

- Aeronautical engineering degree
- US Navy jet aircraft test pilot

APOLLO 12
LUNAR MODULE PILOT

RICHARD GORDON

5 October 1929 –
6 November 2017

- Chemistry degree
- US Navy test pilot
- Gemini 11

APOLLO 12
COMMAND MODULE PILOT

ALAN SHEPARD

18 November 1923 –
21 July 1998

- US Navy test pilot
- Mercury-Redstone 3

APOLLO 14
COMMANDER

JOHN 'JACK' SWIGERT

30 August 1931 –
27 December 1982

- Aerospace engineering Master's degree
- US Air Force jet fighter pilot
- Test pilot for North American Aviation

APOLLO 13
COMMAND MODULE PILOT

FRED HAISE

b. 14 November 1933

- Aeronautical engineering degree
- US Marine Corps jet fighter pilot
- NASA research test pilot

APOLLO 13
LUNAR MODULE PILOT

HARRISON 'JACK' SCHMITT

b. 3 July 1935

- Geology doctorate
- Air Force jet pilot training

APOLLO 17
LUNAR MODULE PILOT

RONALD EVANS

10 November 1933 –
7 April 1990

- Aeronautical engineering Master's degree
- US Navy fighter pilot
- Member of astronaut support crew for Apollo 7 and 11 missions

APOLLO 17
COMMAND MODULE PILOT

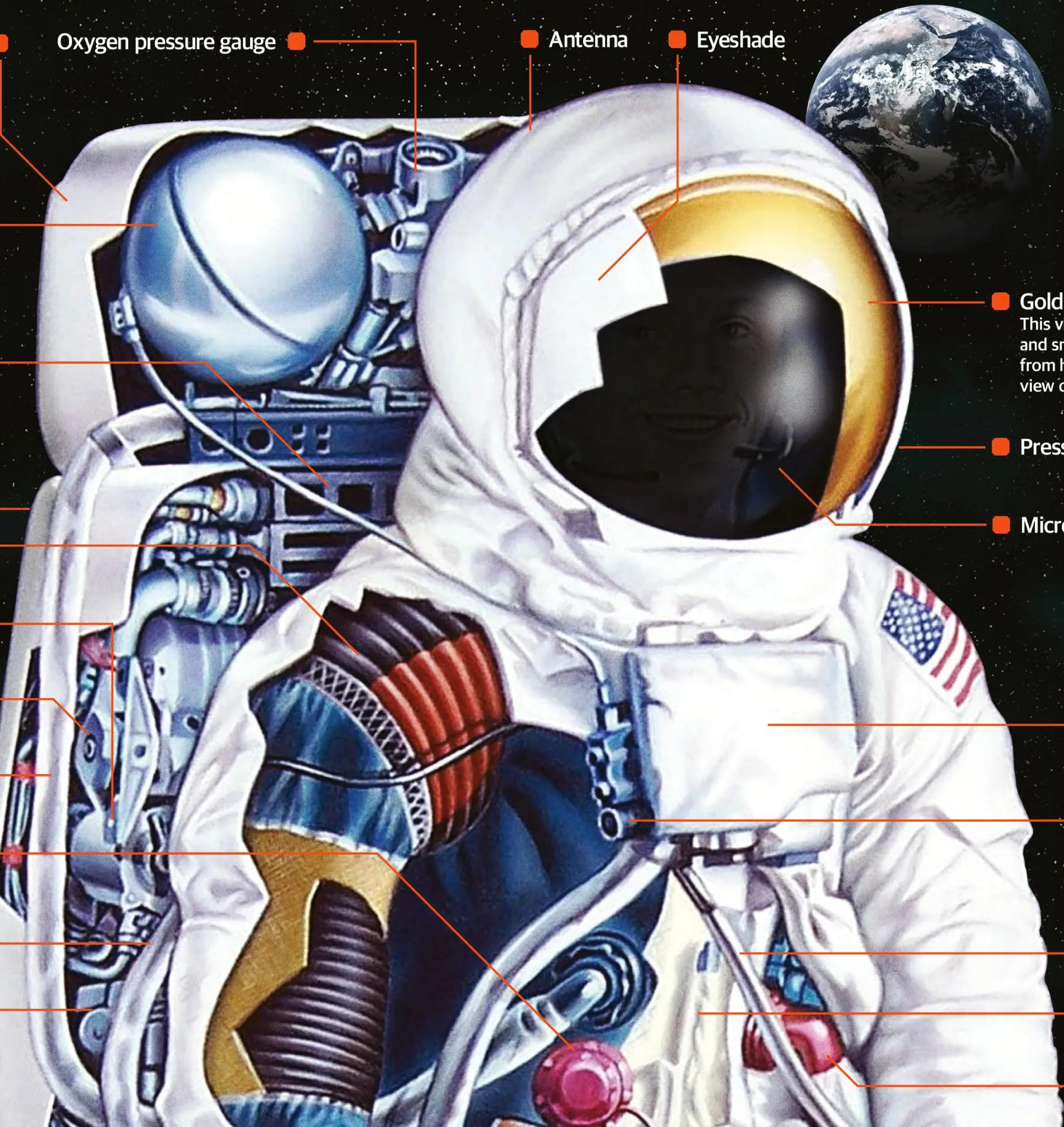
KEY:

Entered lunar orbit

Walked on Moon

The Apollo spacesuit

Inside the suits that Neil Armstrong and Buzz Aldrin wore on the Moon during Apollo 11



Emergency oxygen system
In the case of the primary system failing, this emergency system would immediately supply oxygen to maintain the suit's pressure.

Oxygen pressure gauge

Antenna

Eyeshade

Emergency oxygen container

Communications radio

Backpack with oxygen and cooling systems
Combined, the Apollo spacesuit and backpack weighed around 82kg (180lb) on Earth but only 14kg (30lb) on the Moon.

Bellows for flexible joint

Oxygen dehumidifier

Oxygen circulating fan

Emergency oxygen tube

Emergency valve pressure and ventilation

Oxygen tube

Coolant water pump

Gold-coated Sun visor
This visor prevented fogging and smudges, as well as the Sun, from hampering an astronaut's view on the lunar surface.

Pressure-tight helmet

Microphone

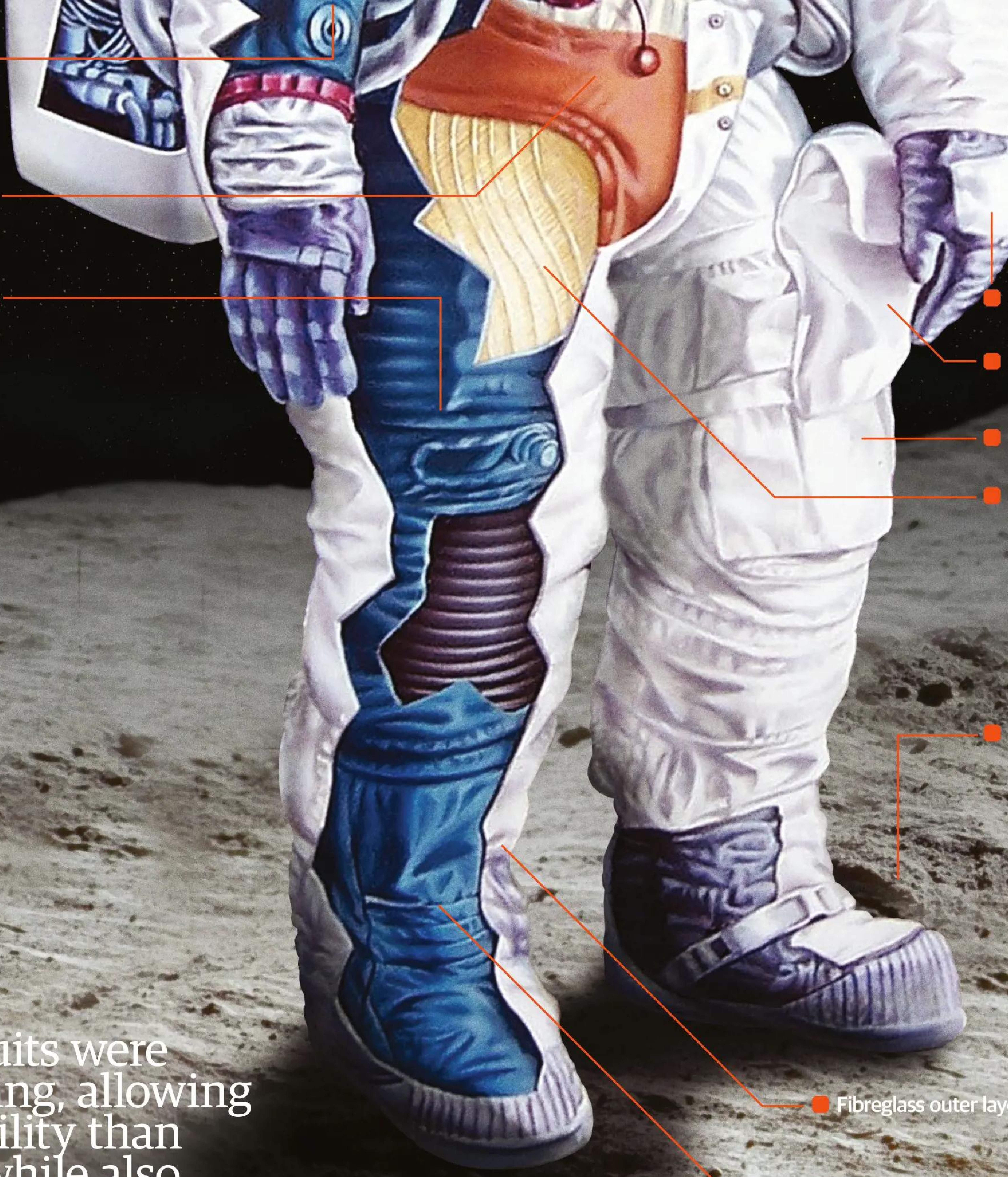
Backpack remote control unit
The Portable Life Support System (PLSS), which purified the air and circulated water in the suit, was controlled with the Remote Control Unit (RCU).

Emergency oxygen supply switch

Electrical cable

Liquid-coolant tube

Oxygen tube



Pressure gauge

Urine collection assembly

Self-sealing patch for emergency medication
If required, astronauts could administer a hypodermic injection to themselves without compromising the suit's pressure using this patch.

Protective glove

Pocket for rock samples

Utility pocket

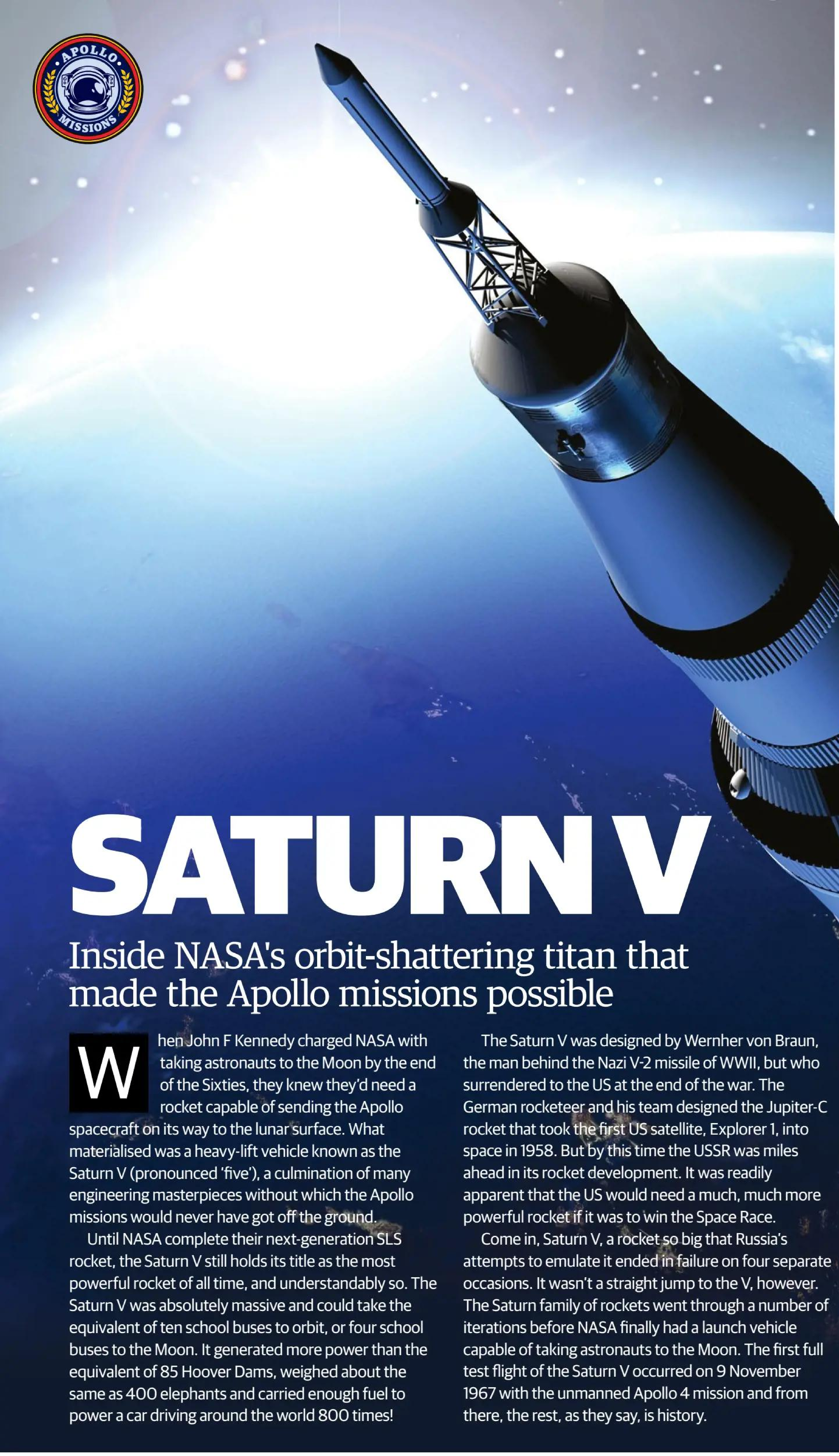
Liquid cooled underwear
A water-cooled nylon undergarment ensured the Apollo astronauts remained at a moderate temperature while they were operating on the lunar surface.

Lunar overshoe with tractor-tread soles

Fibreglass outer layer

Rubber pressure-tight layer

> "The Apollo suits were groundbreaking, allowing greater flexibility than ever before, while also being lightweight"



As of May 2019, the Saturn V is the most powerful rocket of all time – and by some margin

SATURN V

Inside NASA's orbit-shattering titan that made the Apollo missions possible

When John F Kennedy charged NASA with taking astronauts to the Moon by the end of the Sixties, they knew they'd need a rocket capable of sending the Apollo spacecraft on its way to the lunar surface. What materialised was a heavy-lift vehicle known as the Saturn V (pronounced 'five'), a culmination of many engineering masterpieces without which the Apollo missions would never have got off the ground.

Until NASA complete their next-generation SLS rocket, the Saturn V still holds its title as the most powerful rocket of all time, and understandably so. The Saturn V was absolutely massive and could take the equivalent of ten school buses to orbit, or four school buses to the Moon. It generated more power than the equivalent of 85 Hoover Dams, weighed about the same as 400 elephants and carried enough fuel to power a car driving around the world 800 times!

The Saturn V was designed by Wernher von Braun, the man behind the Nazi V-2 missile of WWII, but who surrendered to the US at the end of the war. The German rocketeer and his team designed the Jupiter-C rocket that took the first US satellite, Explorer 1, into space in 1958. But by this time the USSR was miles ahead in its rocket development. It was readily apparent that the US would need a much, much more powerful rocket if it was to win the Space Race.

Come in, Saturn V, a rocket so big that Russia's attempts to emulate it ended in failure on four separate occasions. It wasn't a straight jump to the V, however. The Saturn family of rockets went through a number of iterations before NASA finally had a launch vehicle capable of taking astronauts to the Moon. The first full test flight of the Saturn V occurred on 9 November 1967 with the unmanned Apollo 4 mission and from there, the rest, as they say, is history.

The statistics...

Saturn V

Height: 111m (363ft)

Weight: 2.8mn kg (6.2mn lb)

Payload to orbit: 118,000kg (260,145lb)

Payload to the Moon: 43,500kg (95,901lb)

First launch: 9 November 1967

Last launch: 14 May 1973

Number of launches: 13

Journey to takeoff

Highlighting some of the key events in the development of the Saturn V

1953
Research

The USA begins research into a 450,000kgf (1mn lbf) thrust engine at Rocketdyne in California, with feasibility established a few years later.

1956
First test

For the first time a US-built liquid rocket with a thrust in excess of 400,000kgf (880,000lbf) was test fired at NASA's field lab in Santa Susana, CA.

1958
Jupiter

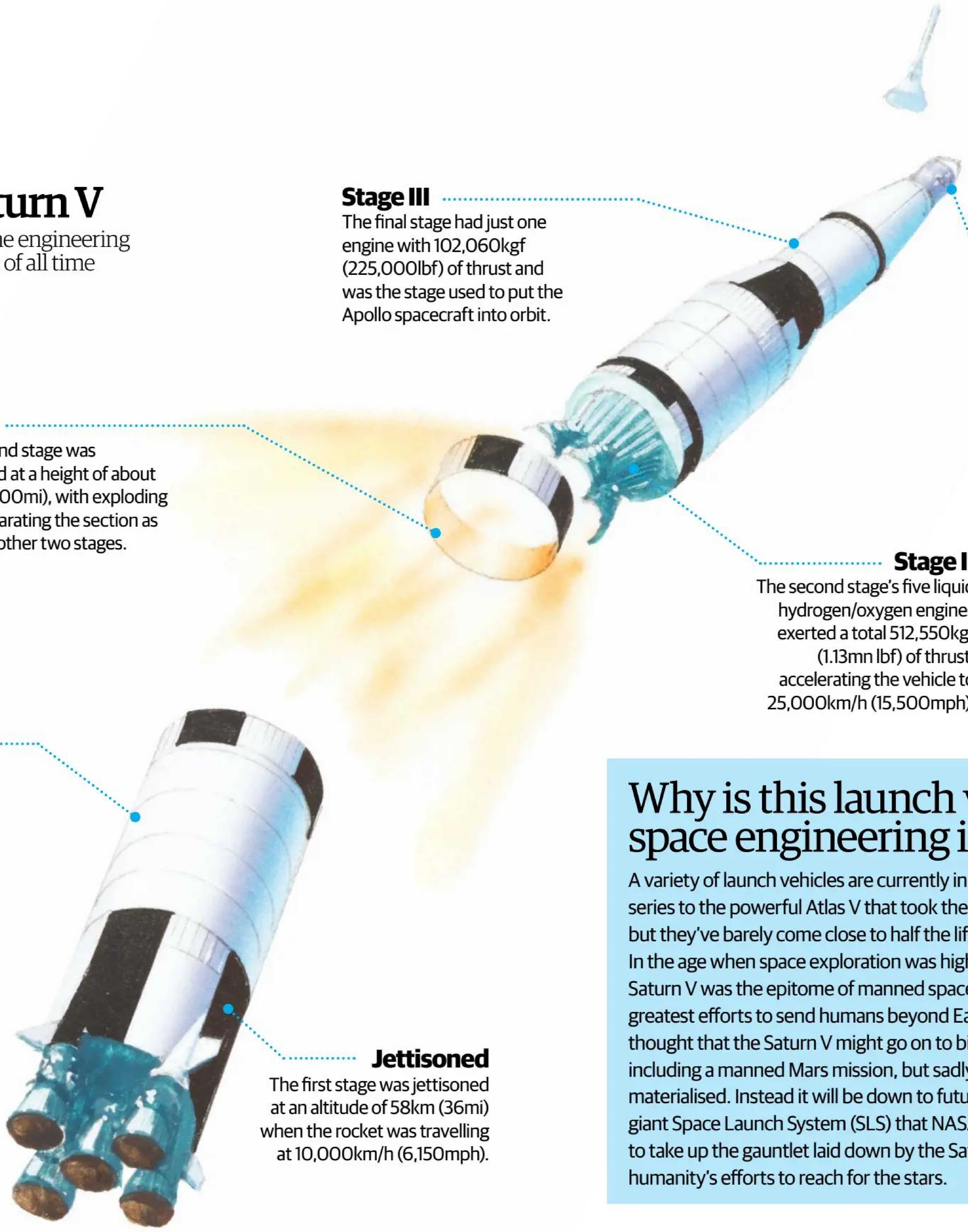
A Jupiter-C rocket takes the first American satellite, Explorer 1, into orbit. Wernher von Braun dubbed the Jupiter series of rockets 'an infant Saturn'.

1961
Saturn I

A test flight of a precursor to the Saturn V – known as the Saturn I (right) – saw the rocket reach suborbit (about 136.5km/84.8mi above Earth's surface).

Inside the Saturn V

We take a closer look at the engineering behind the biggest rocket of all time



Stage III
The final stage had just one engine with 102,060kgf (225,000lbf) of thrust and was the stage used to put the Apollo spacecraft into orbit.

Apollo
Once the third stage had put the Apollo spacecraft on a lunar trajectory it was jettisoned, sending the astronauts on their way to the Moon.

Bolts
The second stage was jettisoned at a height of about 160km (100mi), with exploding bolts separating the section as with the other two stages.

Stage II
The second stage's five liquid hydrogen/oxygen engines exerted a total 512,550kgf (1.13mn lbf) of thrust, accelerating the vehicle to 25,000km/h (15,500mph).

Stage I
The first stage of the Saturn V used liquid oxygen and kerosene to produce 3.4mn kgf (7.5mn lbf) across five engines.

Jettisoned
The first stage was jettisoned at an altitude of 58km (36mi) when the rocket was travelling at 10,000km/h (6,150mph).

Why is this launch vehicle a space engineering icon?

A variety of launch vehicles are currently in operation, from the Delta series to the powerful Atlas V that took the Curiosity rover to Mars, but they've barely come close to half the lifting power of the Saturn V. In the age when space exploration was high on political agendas, the Saturn V was the epitome of manned space missions and signified our greatest efforts to send humans beyond Earth orbit. It was widely thought that the Saturn V might go on to bigger and better things, including a manned Mars mission, but sadly such endeavours never materialised. Instead it will be down to future rockets, such as the giant Space Launch System (SLS) that NASA is currently developing, to take up the gauntlet laid down by the Saturn V and continue humanity's efforts to reach for the stars.

How this mega rocket was built

1 Working inside
In this photo you can get an idea of the rocket's scale as Boeing technicians work on the interior of the Saturn V's giant first stage.

2 Stage by stage
The three stages of the Saturn V rocket were manufactured individually before being hoisted together at the end of the process.

3 Transportation
Pictured above is the giant Super Guppy plane that NASA used to transport the stages of the Saturn V to the Vehicle Assembly Building.

4 Assembly line
The Saturn V wasn't just one vehicle; in total 17 of the rockets were manufactured, although only 13 of them were ever launched.

1962
Saturn V
With successful tests under its belt, NASA announces plans to build the most powerful rocket of all time – enter the three-stage Saturn V.

1964
Space Race
A launch of a Saturn IV was heralded by John F Kennedy as the rocket that took the USA ahead of the Soviets in the Cold War-linked Space Race.

1966
Dummy
A full-scale Saturn V dummy rocket was rolled out of the Vehicle Assembly Building (VAB) to the launch pad for an initial dry launch run.

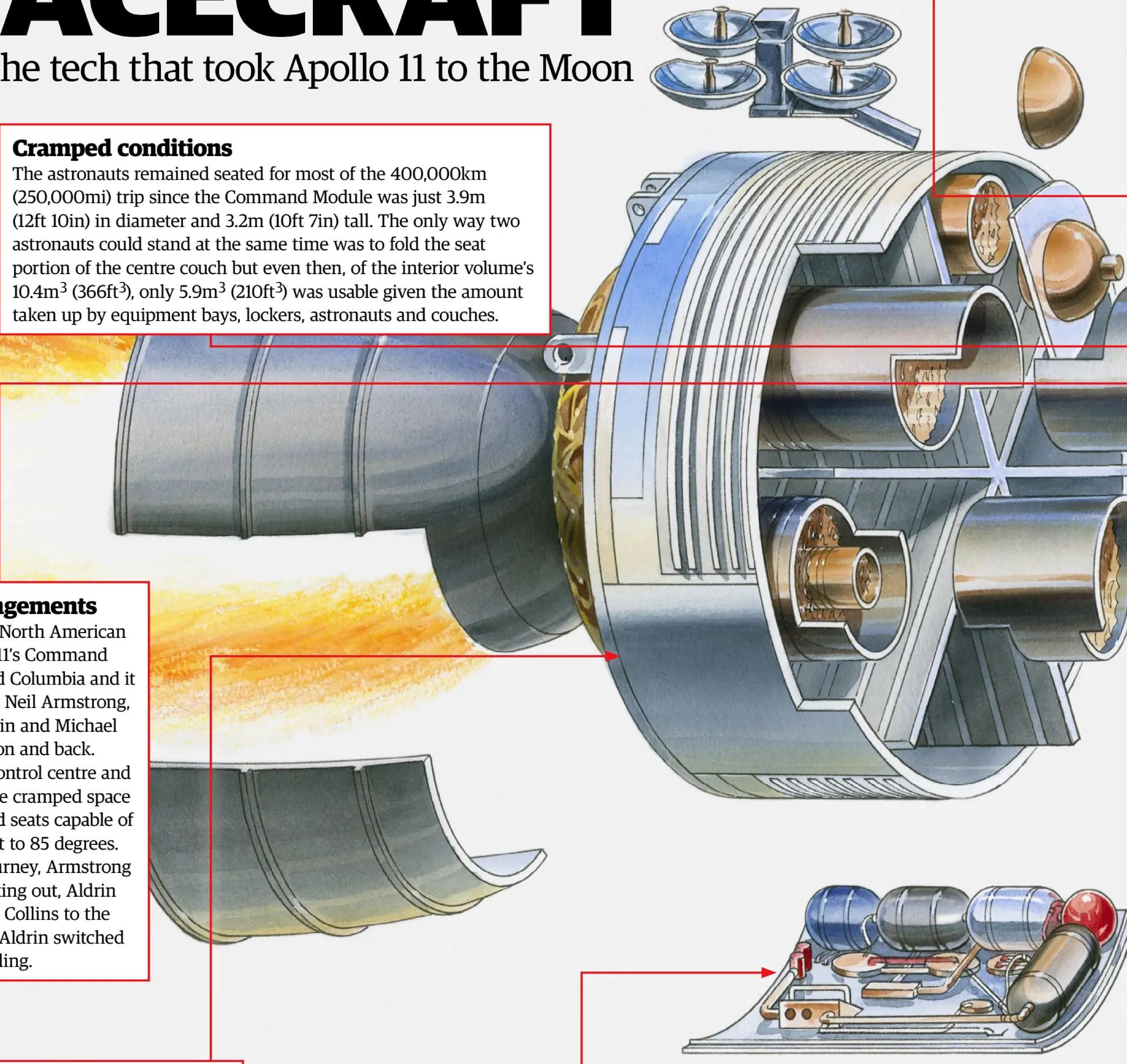
1967
Shaken
NASA announced the successful completion of the dynamic test programme, where a Saturn V was shaken on the ground for 450 hours.

1967
First launch
The first Saturn V was launched with the objectives of testing structure and thermal integrity, both of which were accomplished.

© NASA Boeing, Thinkstock

INSIDE THE APOLLO SPACECRAFT

Explore the tech that took Apollo 11 to the Moon



Heat shield
Given that the temperature on the surface of the Command Module reached as high as 2,760°C (5,000°F) during its descent, it was vitally important to protect the crew from being cooked. NASA's engineers, who had worked on the Apollo program since 1961, devised a heat shield that used an ablative coating. As temperatures rose, the coating eroded and the excessive heat was simply reflected away.

Cramped conditions
The astronauts remained seated for most of the 400,000km (250,000mi) trip since the Command Module was just 3.9m (12ft 10in) in diameter and 3.2m (10ft 7in) tall. The only way two astronauts could stand at the same time was to fold the seat portion of the centre couch but even then, of the interior volume's 10.4m^3 (366ft^3), only 5.9m^3 (210ft^3) was usable given the amount taken up by equipment bays, lockers, astronauts and couches.

Seating arrangements
Manufactured by North American Rockwell, Apollo 11's Command Module was called Columbia and it carried astronauts Neil Armstrong, Edwin 'Buzz' Aldrin and Michael Collins to the moon and back. Doubling as the control centre and living quarters, the cramped space had three couched seats capable of adjusting from flat to 85 degrees. For the launch journey, Armstrong sat to the left looking out, Aldrin in the middle and Collins to the right. Collins and Aldrin switched places for the landing.

Service Module
Situated underneath the astronaut couches in the Command Module was the aft section where there were storage lockers, propellant tanks, ten reaction control engines, water tanks, wiring and plumbing. But the power and support systems, as well as Apollo's main engine, were in a separate Service Module that remained linked with the Command Module (forming the Command and Service Module).

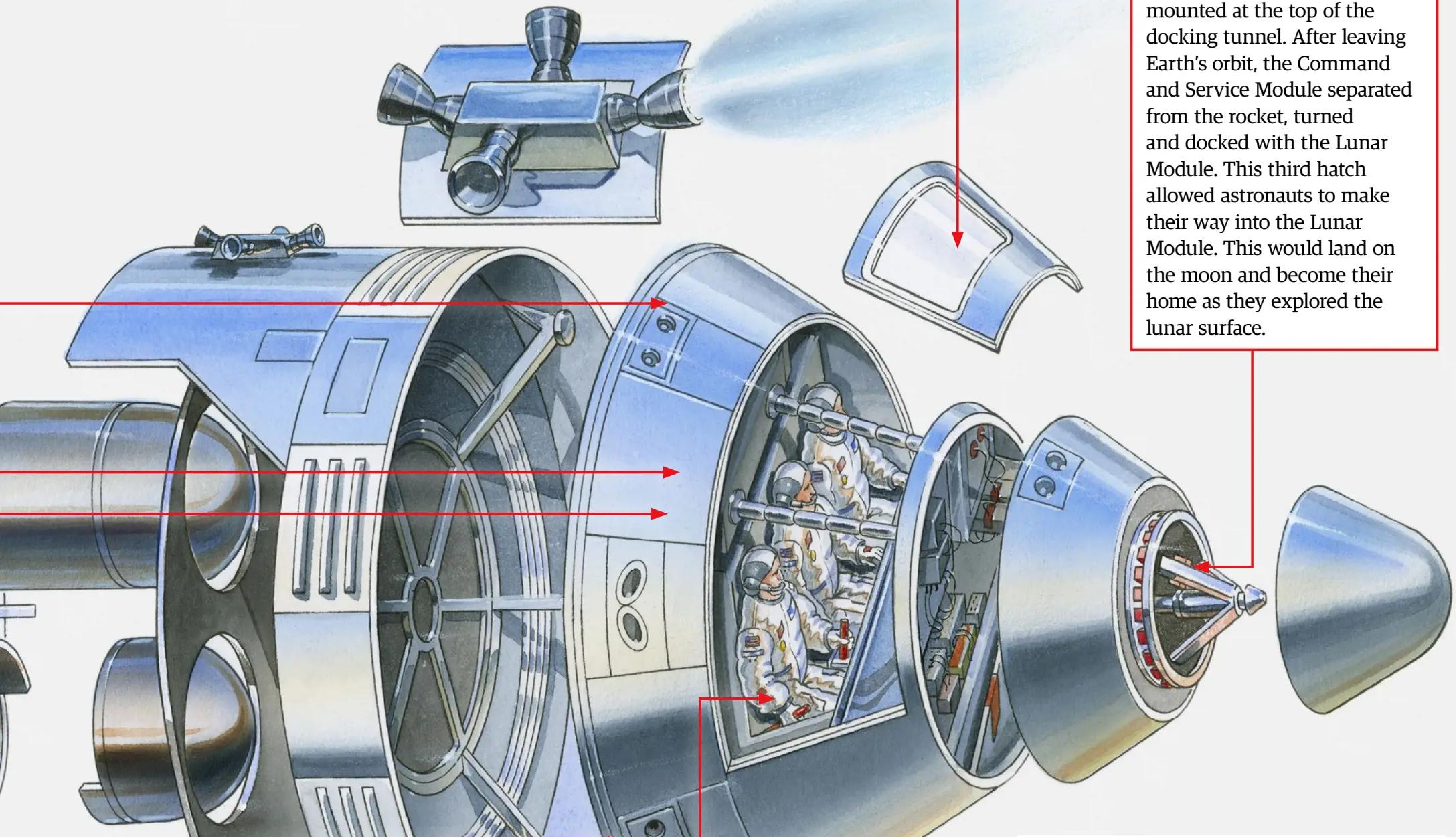
Storage of vital items
Lining bays on the interior walls of the spacecraft was lots of equipment such as emergency medical kits, sanitation supplies, waste management, water, clothing and food (the first meal they ate was beef, potatoes and grape juice). Michael Collins also drew a small calendar on a section of smooth wall underneath one of the lockers. The dates 16 to 23 July 1969 were crossed out, leaving just 24 - the day of the landing.

Amazing views

The astronauts could gaze at the stars with five windows to look out of. As well as two forward-facing rendezvous windows measuring 200x330mm (8x13in), there were two of 330mm (13in) square on either side of the outer seats and a circular one, 27cm (10.6in) in diameter within the access hatch. Three thick panes of glass were placed within each opening.

Getting in and out

The astronauts climbed aboard the Command Module via one of two side hatches. But there was also a third hatch mounted at the top of the docking tunnel. After leaving Earth's orbit, the Command and Service Module separated from the rocket, turned and docked with the Lunar Module. This third hatch allowed astronauts to make their way into the Lunar Module. This would land on the moon and become their home as they explored the lunar surface.

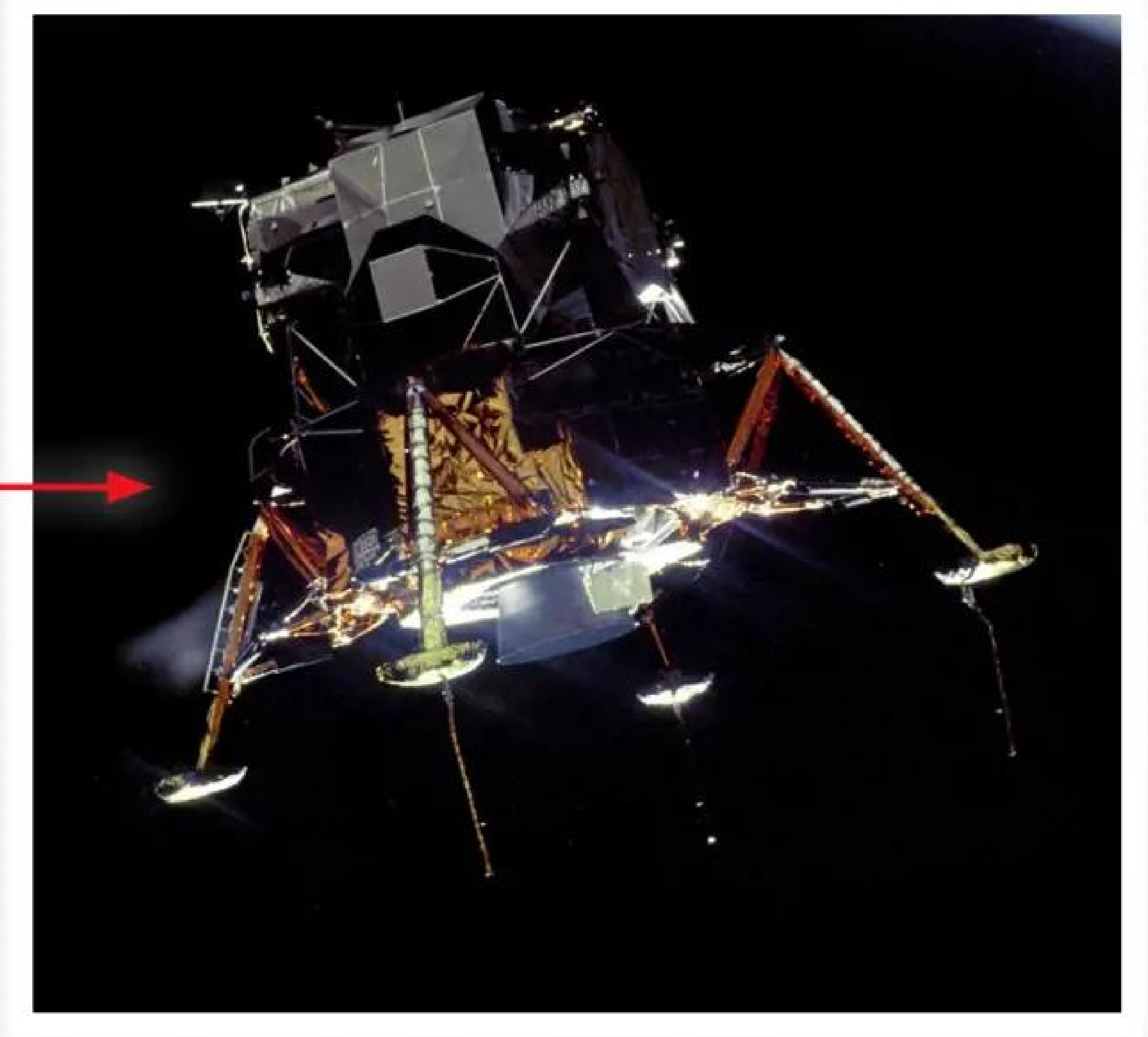


Forward compartment

The Command Module was split into three compartments. As well as the part housing the crew, there was a forward section in the nose of the cone that was itself divided into four segments. Covered by a heat shield, it contained Earth-landing equipment such as the parachutes, sea recovery sling, recovery antennas and beacon light. It also included a couple of reaction control engines and the forward heat shield release mechanism.

Controlling the crafts

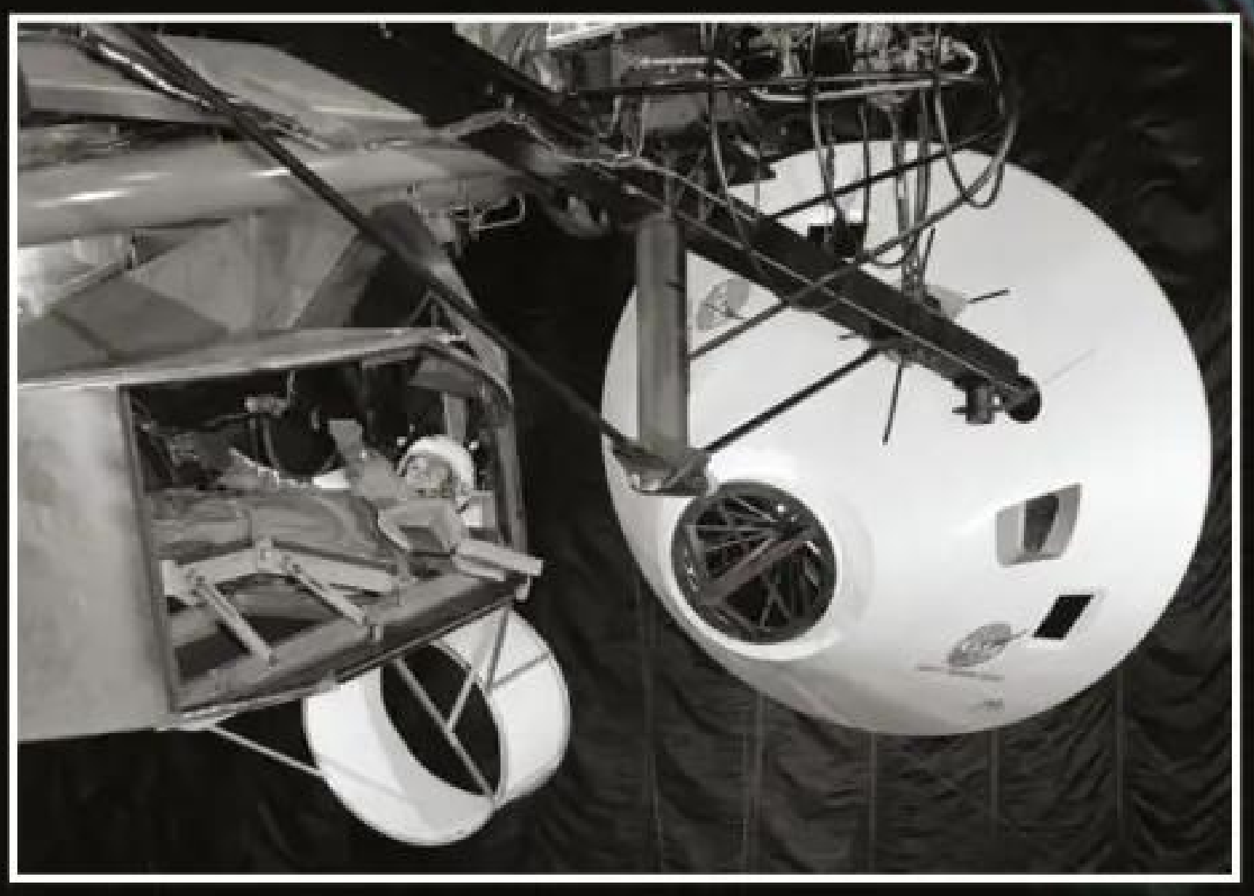
Astronauts on board the Command Module could make use of a 2.1x0.9m (7x3ft) main display console and its accompanying wings, managing communications, fuel, the electrics and other functions via toggle and push switches. The ascent stage of the Lunar Module was less sophisticated but it had instrument panels and flight controls along with its own hypergolic propellant tanks to return it back to the Command and Service Module.



Lunar Module

While Collins stayed on the Command Module, two of the three astronauts – Armstrong and Aldrin – entered the Lunar Module. Devised in two parts – with ascent and descent stages – it landed on the moon on four splayed, shock-absorbing legs and the astronauts went outside by climbing through a hatch and down a set of ladders. The astronauts had to stand to control the vehicle and they were able to communicate with mission control via antenna.

A fish-eye lens view of the Lunar Module interior during training for the Apollo 9 mission



First used for the Gemini missions, the Rendezvous Docking Simulator was modified and used to build on docking techniques for the Apollo programme

INSIDE THE APOLLO LUNAR MODULE

Take a look inside a lunar spacecraft, at the control systems that allowed astronauts to put successive Apollo missions onto the Moon

Even though Apollo was in the Sixties, when microchips were a brand-new technology and the complicated gizmos of today were nothing but science fiction, the Lunar Module's controls took on a remarkably complicated appearance, with switches, buttons, knobs, lights and controls making up a crescent-shaped display in the cockpit.

The main control was the DSKY; this enabled the crew to interface with the Apollo Guidance Computer, which controlled the navigation of the Lunar Module. This computer was the height of computing power in the late-Sixties with a 16-bit memory. The Command Module actually had two of these interfaces, while the Lunar Module that would land on the Moon had one and enabled overall control of each spacecraft. DSKY stood for 'Display and Keyboard' and was often pronounced as 'dis-key'. It looked like a glorified calculator. The Apollo astronauts would enter commands into the DSKY that were given as two digit numbers. One form of number were called 'verbs' and specified the type of command, while a 'noun' indicated which data was to be affected by the action.

The mission commander – on Apollo 11 this was Neil Armstrong – controlled the flight controls and engine throttle while the Lunar Module pilot, Buzz Aldrin, controlled spacecraft systems, informing the commander on the status of the Lunar Module as it descended to the Moon as well as navigational information. Vital to this latter part was the Alignment Optical Telescope, which was used to identify features on the lunar surface as the Lunar Module closed in on its landing site, which in the case of Apollo 11 was the Sea of Tranquility. The telescope also provided an independent confirmation of what the guidance computer was telling the crew.

Not everything always worked smoothly, however. As Armstrong and Aldrin prepared to blast off from the Moon in the Lunar Module's ascent stage, to rendezvous with Michael Collins in the Command Module, they found a significant problem. The switch for the circuit breaker that would allow the lunar guidance system to automatically ignite the ascent stage engines had broken when Aldrin accidentally bashed into it with his spacesuit backpack. Fortunately, Aldrin was able to jimmy the system by pushing the broken circuit breaker all the way in with a pen.

Despite mostly being test pilots, the NASA astronauts of the Sixties still had much to learn about space flight and the control of the vehicles that would take them there. Manoeuvring a craft in the weightlessness of space is an entirely different proposition to flying a jet fighter through Earth's

> "Buzz Aldrin was able to jimmy Apollo 11's broken circuit breaker all the way in with a pen"

skies. To sharpen their skills and become better acquainted with the vehicles that would take astronauts on their perilous journeys into orbit and to the Moon, an elaborate simulator was built. Initially used to train astronauts on the Gemini programme, the Rendezvous Docking Simulator (also known as the Real-Time Dynamic Simulator) was soon adapted for the Apollo crews training to go to the Moon.

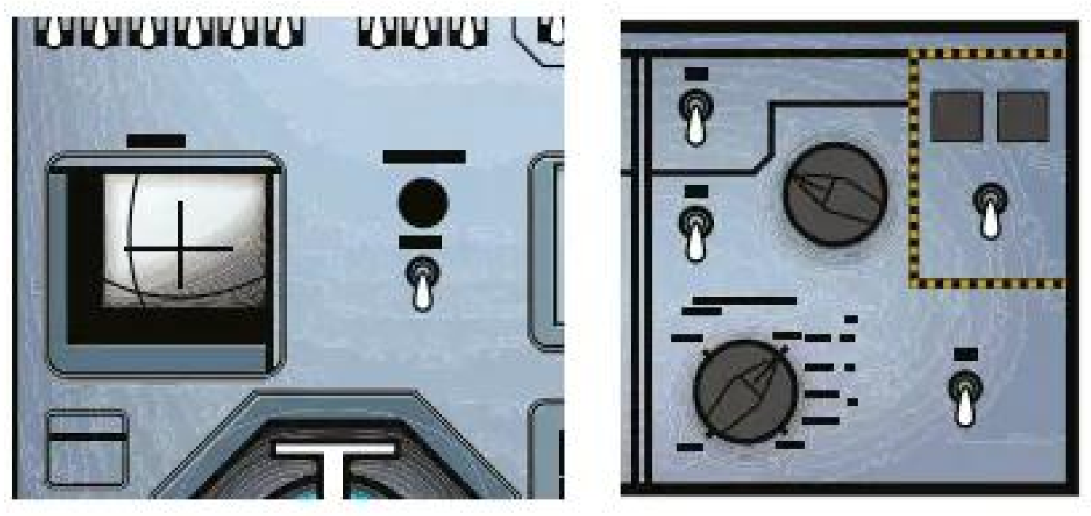
Based at NASA's Langley Research Center, the simulator mimicked the disorientating feeling of zero gravity by using a gimbal that could pitch and yaw along three axes, suspended on eight cables. High above the chain dangled from an overhead crane that could move at six metres (20 feet) per second. Rather than having to battle against random movements in six degrees of freedom, astronauts in training could utilise the multi-directional simulator to help them adapt to working in three dimensions.

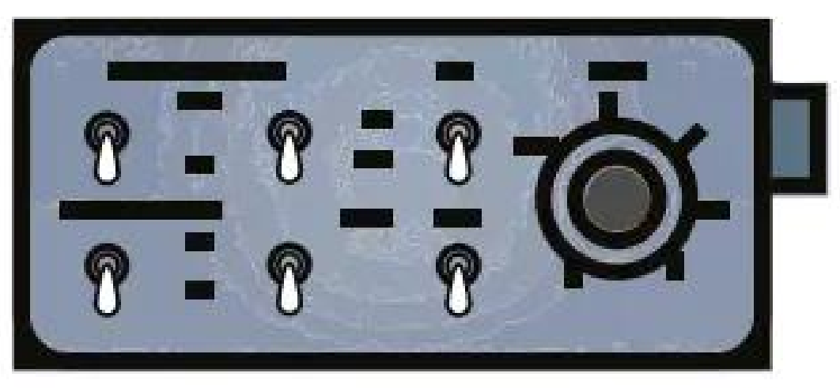
The systems on the Lunar Module and the Command Module were both complicated and primitive. During training the Apollo astronauts would sit in pretend cockpits with working replicas of the computers, running through procedures and figuring out what to do if things went wrong, which they often did, by learning the error codes and the correct responses if a particular light showed.

Most crucial for the 1969-1972 Apollo missions was the Command Module being able to rendezvous and dock with the Lunar Module's ascent stage, as it returned astronauts from the Moon's surface. Should the two fail to reconnect, the astronauts on the Lunar Module would likely become stranded in space. There was no margin for error and the Rendezvous Docking Simulator proved its worth when the six Apollo missions worked flawlessly to put men on the Moon. All the Apollo crews trained on the simulator and today it survives, hanging from the rafters of the Langley Research Center in Virginia. Having been declared a National Historic Landmark, its continued existence has been guaranteed, although it is currently not in use.

Despite the dangers, every mission that reached the Moon returned home, thanks to the astronauts' intense training, expert knowledge and the remarkable success of the primitive computers used to guide a manned mission to the Moon and back.

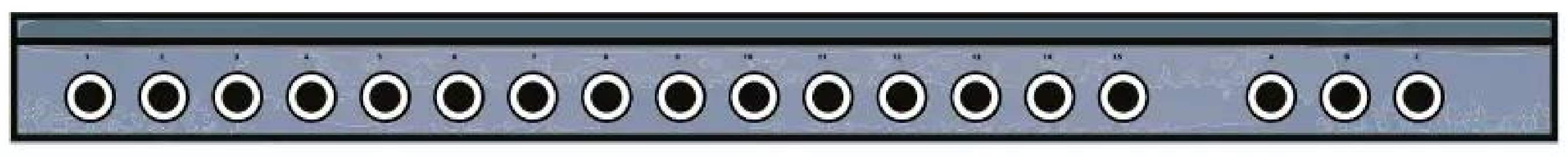
The control panel



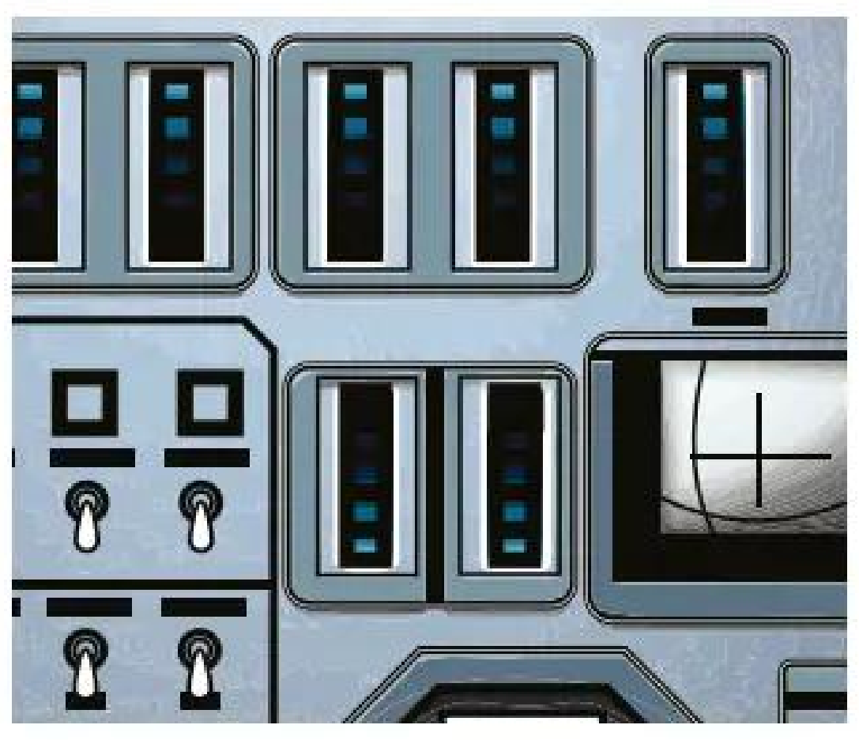


Orbital Rate Display (out of shot)
The ORD provided the correct signal to rotate the Flight Director Attitude Indicator (FDAI) at a rate that matched the orbital period. If the ORD was initialised correctly, the FDAI would display altitudes relative to the surface below.

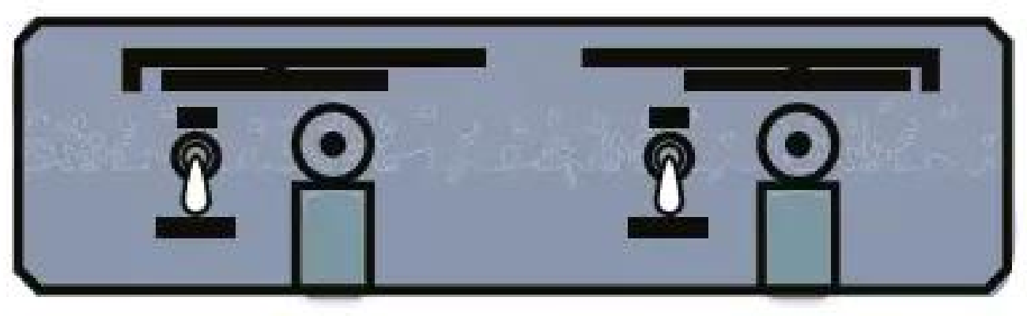
Contact Lights
The contact lights indicated to the module's crew that they were in close proximity to the Moon's "surface" and that they should cut the Descent Propulsion System (DPS) engine.



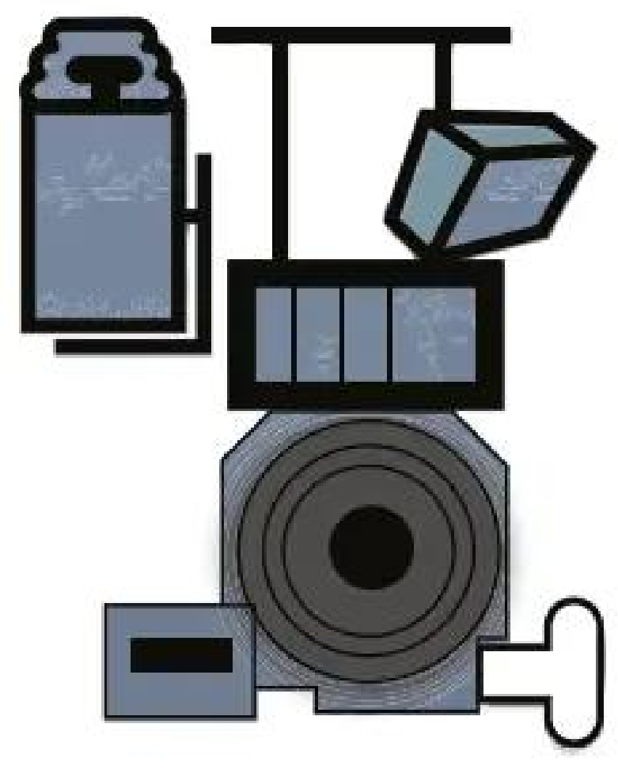
Broken Engine Circuit Breaker
Used to arm the Ascent Propulsion System engine, the circuit breaker's knob was broken off during Apollo 11's return.

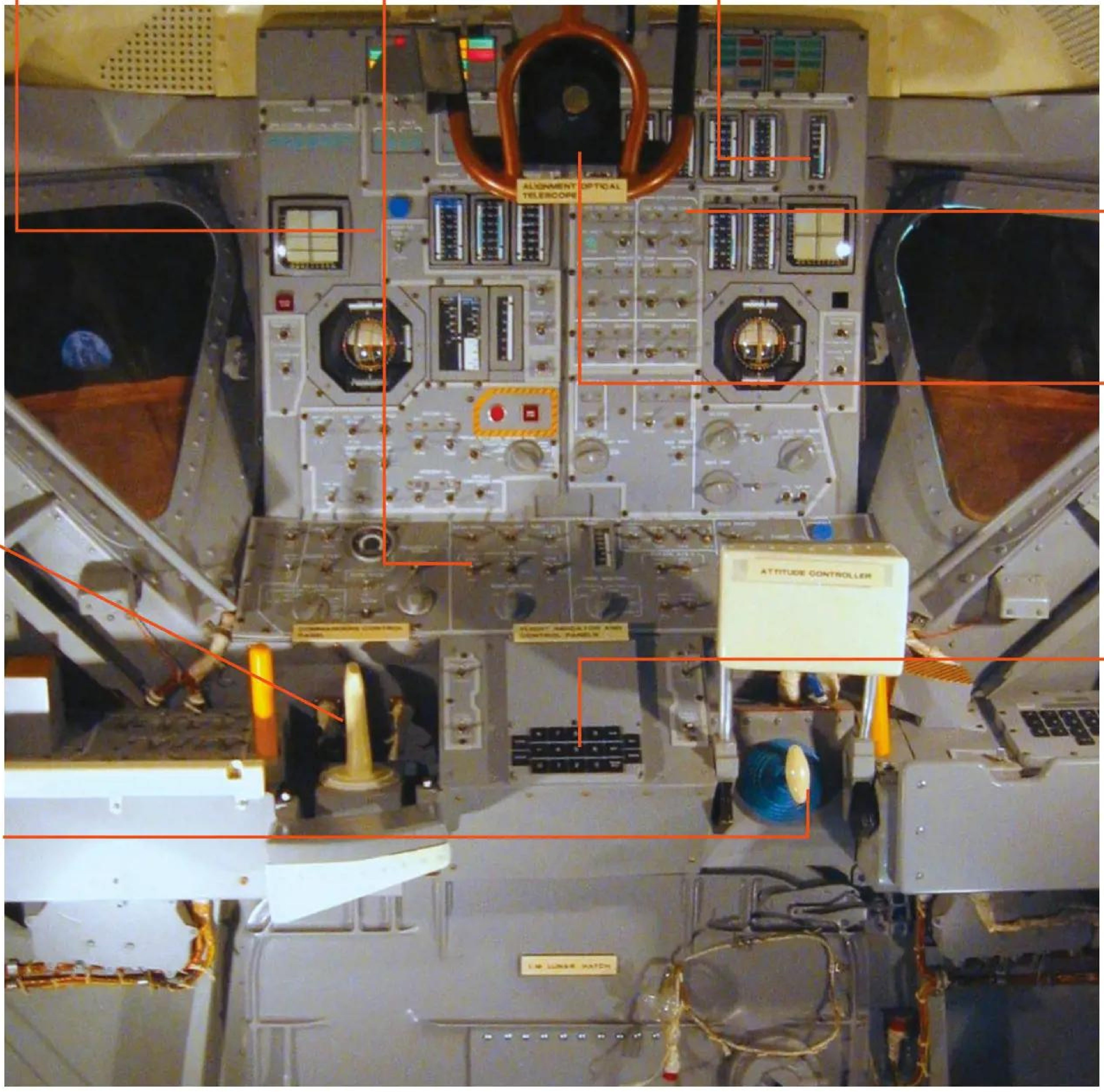


Carbon Dioxide Partial Pressure
This indicated the level of carbon dioxide. Apollo 13 experienced the explosion of an oxygen tank causing a multitude of failures and forcing the astronauts to use the LM as a lifeboat.

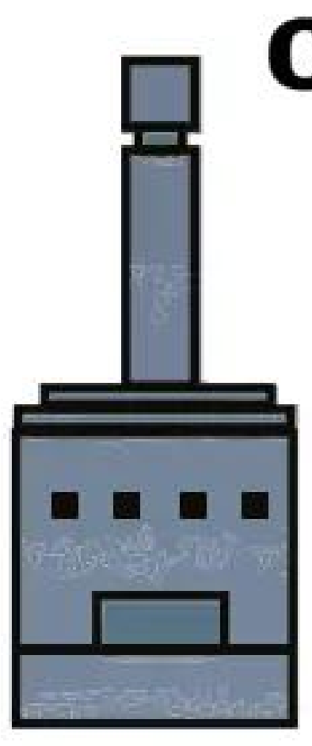


Utility Light Switch Assembly
When required, utility lights were used to supplement the cabin interior lighting and connect to the overhead utility light panel. Switches allowed astronauts control over light intensity.



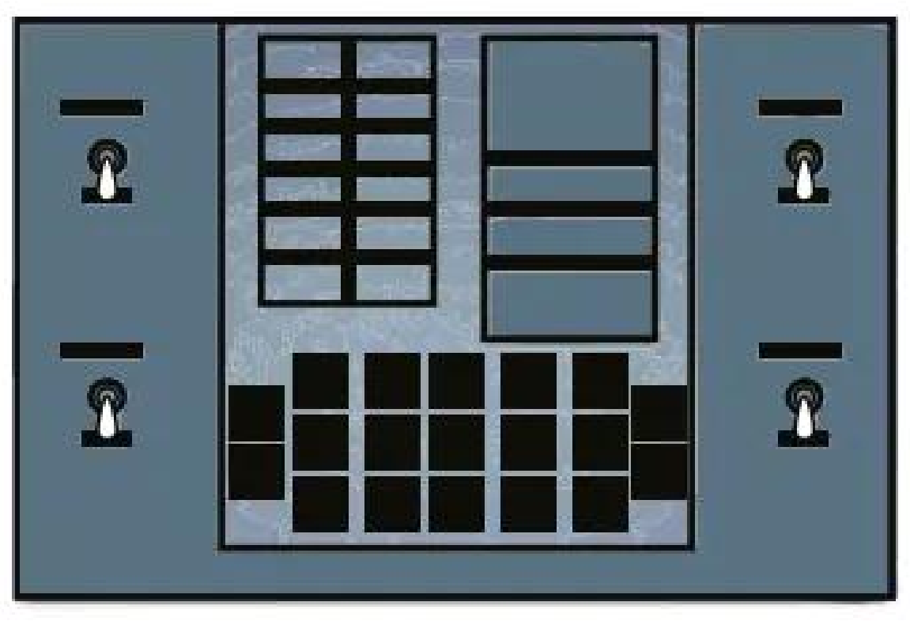


The Alignment Optical Telescope (AOT)
Used by the astronauts for navigation while in the Apollo Lunar Module (LM), the AOT was a periscope-type device that protruded through the top of the LM to make direct visual sightings and precise measurements.



Attitude Controllers
The attitude controllers maintained or changed the angle of the spacecraft during a maneuver.

Display and Keyboard (DSKY) Interface
The DSKY interface for the Apollo Guidance Computer (AGC), the most essential piece of kit on the spacecraft, governed the control of the Command Module.



Thrust Controller
This joystick allowed the astronaut to control the forward, backward and sideways movement of the LM flew using the jets. It could also be used as a throttle to control the descent engine.

© NASA; Peters & Zabranski

Small Steps

36 The tragedy of Apollo 1

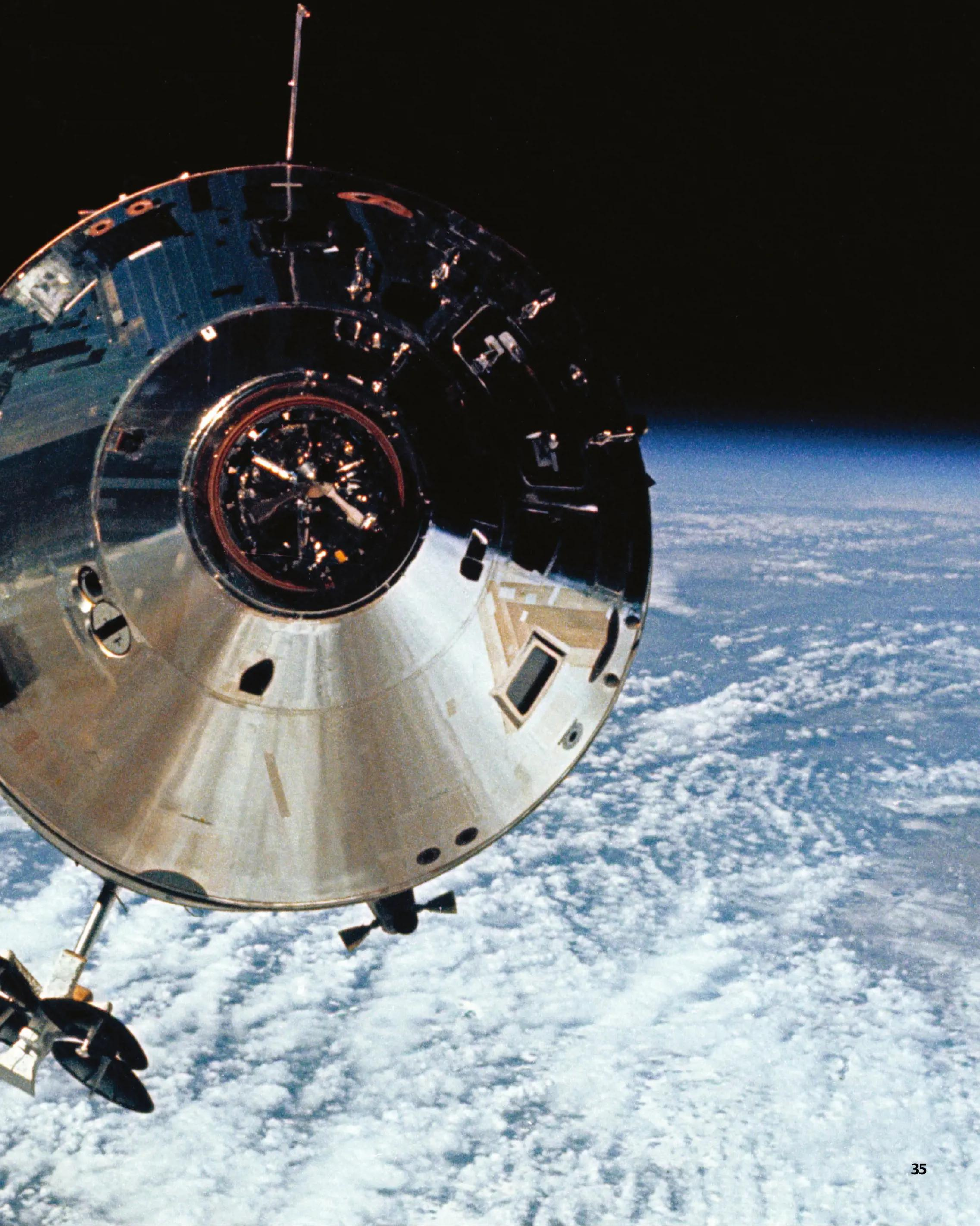
44 Lost missions: the Apollo test flights

48 Apollo 7: success for spacecraft and crew

54 Apollo 8: first flight to the Moon

60 Apollo 9: the Lunar Module's debut

66 Apollo 10: the dress rehearsal



V.I. GRISSOM
E.H. WHITE
NASA
APOLLO

Main:
The Apollo 1 crew pose for photographs at the launch complex in Florida, just ten days before the accident

The tragedy of APOLLO 1

How NASA's first fatal space disaster shaped the future of the programme

Reported by Elizabeth Howell

© NASA JSC

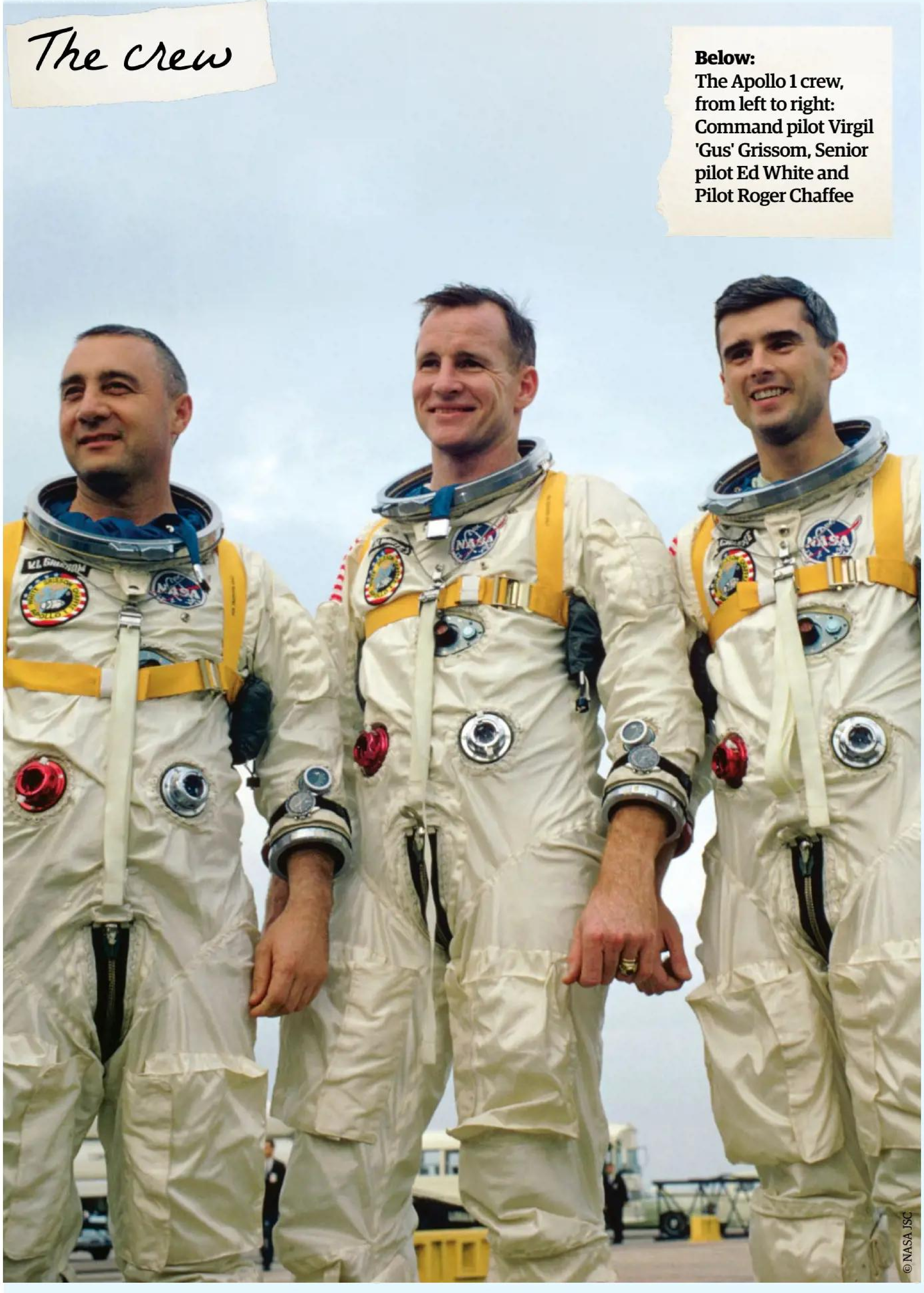
The Apollo programme changed forever on 27 January 1967, when a flash fire swept through the Apollo 1 command module during a launch rehearsal test. The three men inside perished despite the best efforts of the ground crew. It would take more than 18 months, and extensive redesigns, before NASA sent more men into space.

NASA had a lofty goal, set by President John F Kennedy in 1961, to land a man on the Moon and return him safely to Earth by the end of the decade. Earlier Mercury and Gemini flights had been the first steps toward that goal, testing how humans behaved in space and how to perform technical spacecraft procedures such as rendezvous. Now the Apollo missions would take astronauts all the way to the Moon for orbital missions and landing missions. The first manned mission in the programme - an Earth-orbiting mission - was originally designated Apollo Saturn-204, or AS-204, but was later renamed Apollo 1.

The Apollo 1 fire was a difficult time for NASA and its astronauts, but the improvements in astronaut safety allowed the agency to complete the rest of the programme with no further fatalities. The agency also met Kennedy's goal of landing a man on the Moon in 1969, with Apollo 11.

NASA had a special ceremony honoring the Apollo 1 astronauts on the 50th anniversary of their deaths in 2017, which included unveiling a new

The crew



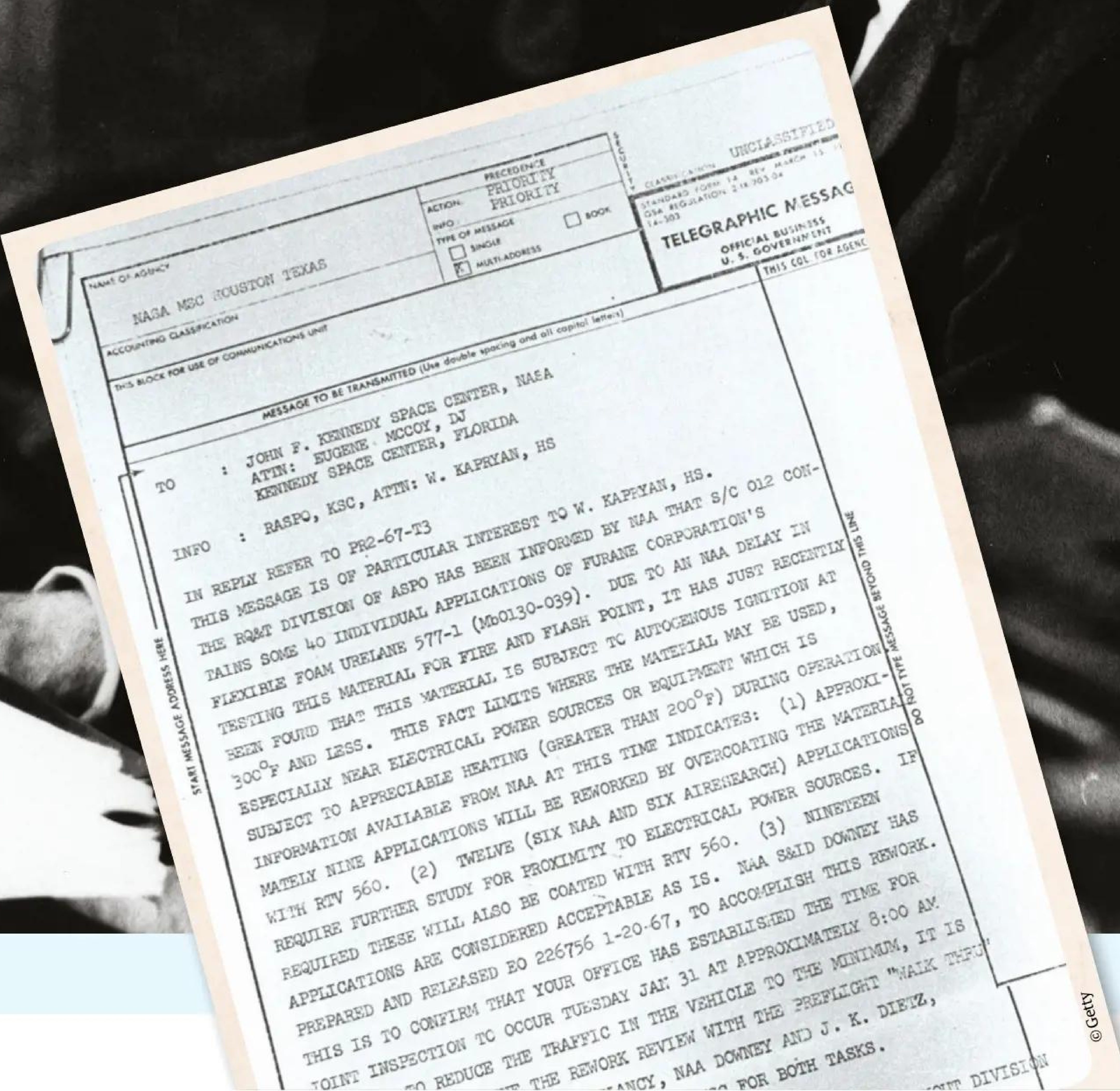
Below:
The Apollo 1 crew, from left to right: Command pilot Virgil 'Gus' Grissom, Senior pilot Ed White and Pilot Roger Chaffee

© NASA JSC

Main:
NASA administrators sit at the witness table before the Senate Committee on Aeronautical and Space Services on the Apollo 1 accident

Right inset:
A draft message by NASA engineer John Dietz, highlighting the potential fire hazard in the Apollo spacecraft. It was never sent

© NASA



SECURITY CLASSIFICATION UNCLASSIFIED

STANDARD FORM 14 REV MARCH 15, 19
GSA REGULATION 2-IX-303.04
14-303

TELEGRAPHIC MESSAGE
OFFICIAL BUSINESS
U. S. GOVERNMENT

NAME OF AGENCY: NASA MSC HOUSTON TEXAS

PRECEDENCE
ACTION: PRIORITY
INFO: PRIORITY

TYPE OF MESSAGE
☐ SINGLE
☒ MULTI-ADDRESS
☐ BOOK

ACCOUNTING CLASSIFICATION

THIS BLOCK FOR USE OF COMMUNICATIONS UNIT

THIS COL FOR AGENC

MESSAGE TO BE TRANSMITTED (Use double spacing and all capital letters)

START MESSAGE ADDRESS HERE

DO NOT TYPE MESSAGE BEYOND THIS LINE

TO : JOHN F. KENNEDY SPACE CENTER, NASA
ATTN: EUGENE MCCOY, DJ
KENNEDY SPACE CENTER, FLORIDA

INFO : RASPO, KSC, ATTN: W. KAPRYAN, HS

IN REPLY REFER TO PR2-67-T3

THIS MESSAGE IS OF PARTICULAR INTEREST TO W. KAPRYAN, HS.
THE RQ&T DIVISION OF ASPO HAS BEEN INFORMED BY NAA THAT S/C 012 CON-
TAINS SOME 40 INDIVIDUAL APPLICATIONS OF FURANE CORPORATION'S
FLEXIBLE FOAM URELANE 577-1 (Mb0130-039). DUE TO AN NAA DELAY IN
TESTING THIS MATERIAL FOR FIRE AND FLASH POINT, IT HAS JUST RECENTLY
BEEN FOUND THAT THIS MATERIAL IS SUBJECT TO AUTOGENOUS IGNITION AT
300°F AND LESS. THIS FACT LIMITS WHERE THE MATERIAL MAY BE USED,
ESPECIALLY NEAR ELECTRICAL POWER SOURCES OR EQUIPMENT WHICH IS
SUBJECT TO APPRECIABLE HEATING (GREATER THAN 200°F) DURING OPERATION
INFORMATION AVAILABLE FROM NAA AT THIS TIME INDICATES: (1) APPROXI-
MATELY NINE APPLICATIONS WILL BE REWORKED BY OVERCOATING THE MATERIAL
WITH RTV 560. (2) TWELVE (SIX NAA AND SIX AIRESEARCH) APPLICATIONS
REQUIRE FURTHER STUDY FOR PROXIMITY TO ELECTRICAL POWER SOURCES. IF
REQUIRED THESE WILL ALSO BE COATED WITH RTV 560. (3) NINETEEN
APPLICATIONS ARE CONSIDERED ACCEPTABLE AS IS. NAA S&ID DOWNEY HAS
PREPARED AND RELEASED EO 226756 1-20-67, TO ACCOMPLISH THIS REWORK.
THIS IS TO CONFIRM THAT YOUR OFFICE HAS ESTABLISHED THE TIME FOR
JOINT INSPECTION TO OCCUR TUESDAY JAN 31 AT APPROXIMATELY 8:00 AM.
TO REDUCE THE TRAFFIC IN THE VEHICLE TO THE MINIMUM, IT IS
THE REWORK REVIEW WITH THE PREFLIGHT "WALK THRU"
ANCY, NAA DOWNEY AND J. K. DIETZ,
FOR BOTH TASKS.
DIVISION

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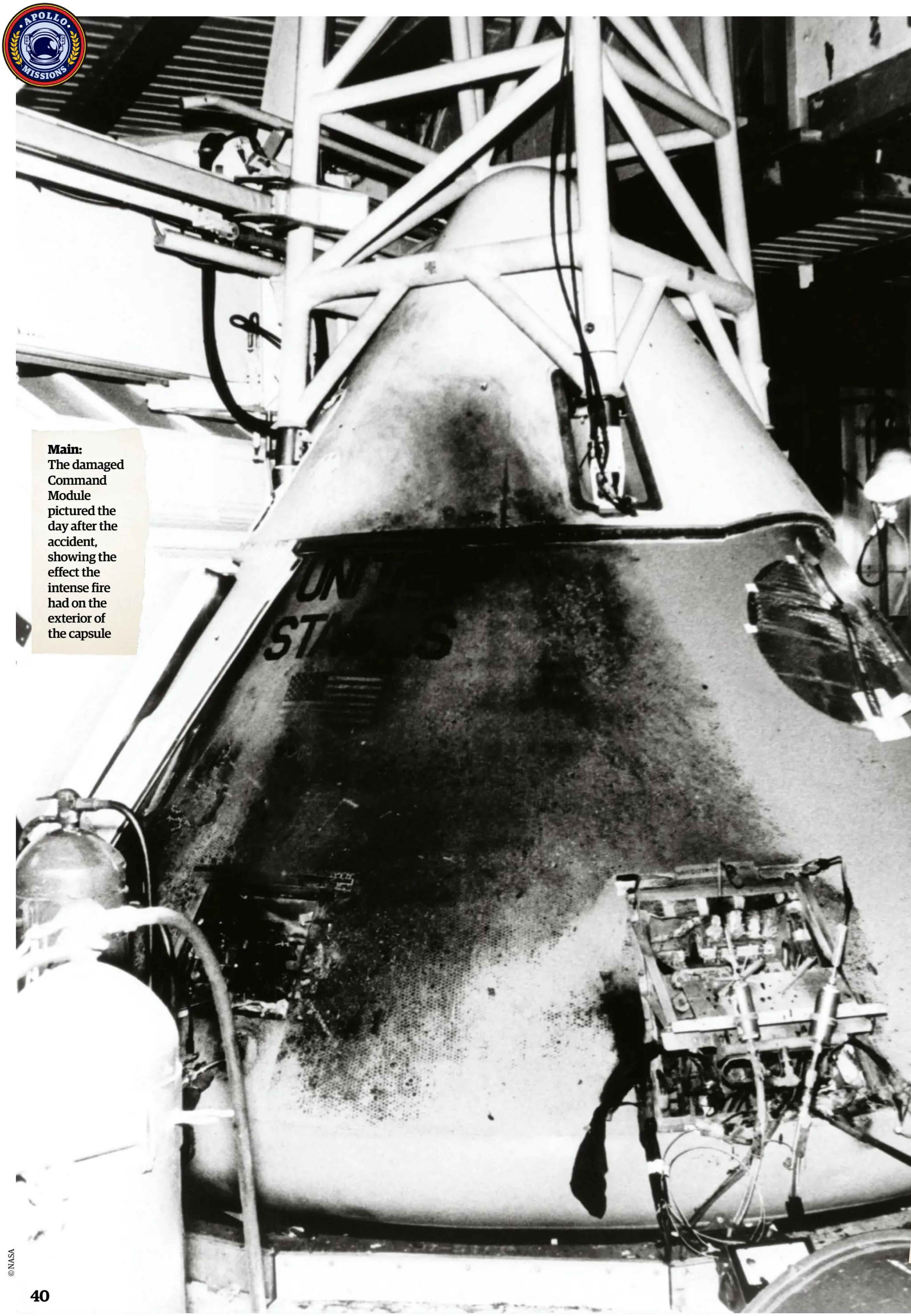


Main: The damaged Command Module pictured the day after the accident, showing the effect the intense fire had on the exterior of the capsule

© NASA

exhibit at the Kennedy Space Center showing the hatches of the damaged command module.

The astronauts

The Apollo 1 crew commander, Virgil "Gus" Grissom, was an Air Force veteran of the Korean War. He was chosen was among NASA's first group of seven astronauts, the Mercury Seven. Grissom was America's second person in space in 1961. On that mission, Mercury's Liberty Bell 7, the hatch door blew for unknown reasons upon splashdown. Grissom ended up in the water and was rescued by a helicopter – which at first tried, in vain, to pick up the spacecraft. The spacecraft was later pulled from the ocean floor in 1999.

Some in the Astronaut Office were skeptical that Grissom's reputation would recover (many believed Grissom blew the hatch; he swore he didn't). However, Grissom successfully commanded the first Gemini flight, Gemini 3, and was selected to do the same for Apollo.

Fellow spaceflight veteran Ed White, an Air Force lieutenant colonel, was the first American to make a spacewalk, on Gemini 4 in 1965. The images of him soaring in space for 23 minutes are still frequently seen today; it is considered one of history's most memorable spacewalks.

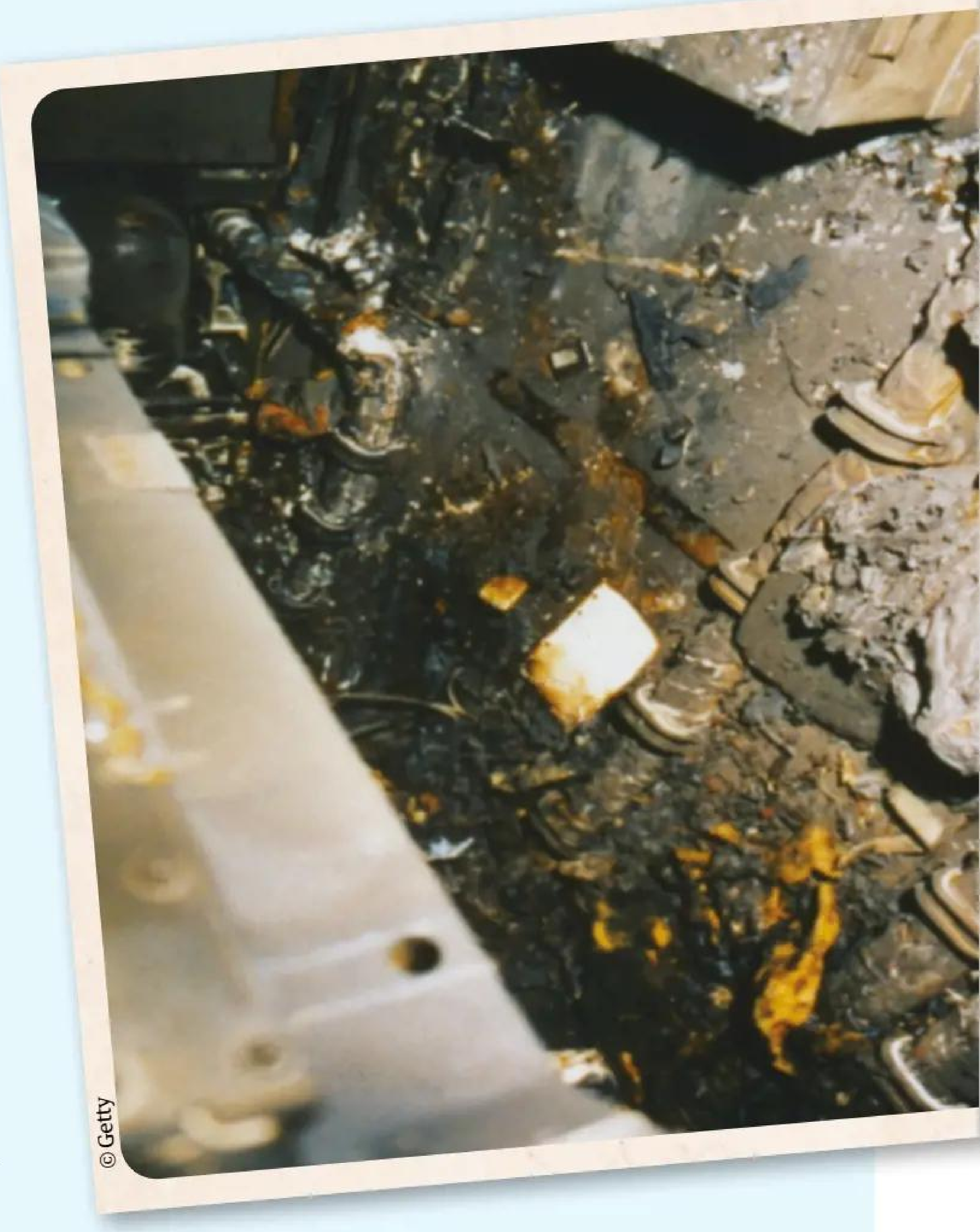
Roger Chaffee was a seasoned Navy lieutenant commander who joined the programme in 1963. Although a rookie in space, he had spent years supporting the Gemini program, most publicly as CapCom on Gemini 4. Now getting a chance to fly after five years in the programme, he said, "I think it will be a lot of fun."

Gone in an instant

Every astronaut in the Apollo programme had flight experience, and many were test pilots. They were used to seeing machines under development and dealing with delays, and assessing the aeroplanes' readiness for flight. In the view of many of these astronauts, the Apollo command module just wasn't ready yet. Engineering changes were still in progress as NASA prepared for the countdown test.

On his last visit home in Texas, 22 January 1967, Grissom grabbed a lemon off a citrus tree in the backyard. His wife, Betty, asked what he was going to do with it. "I'm going to hang it on that spacecraft," he answered as he kissed her goodbye. He hung it on the flight simulator after he arrived at the Cape.

The morning of the test, the crew suited up and immediately detected a foul odour in the breathing oxygen, which took about an hour to fix. Then the communications system acted up. Shouting through the noise, Grissom vented angrily: "How are we



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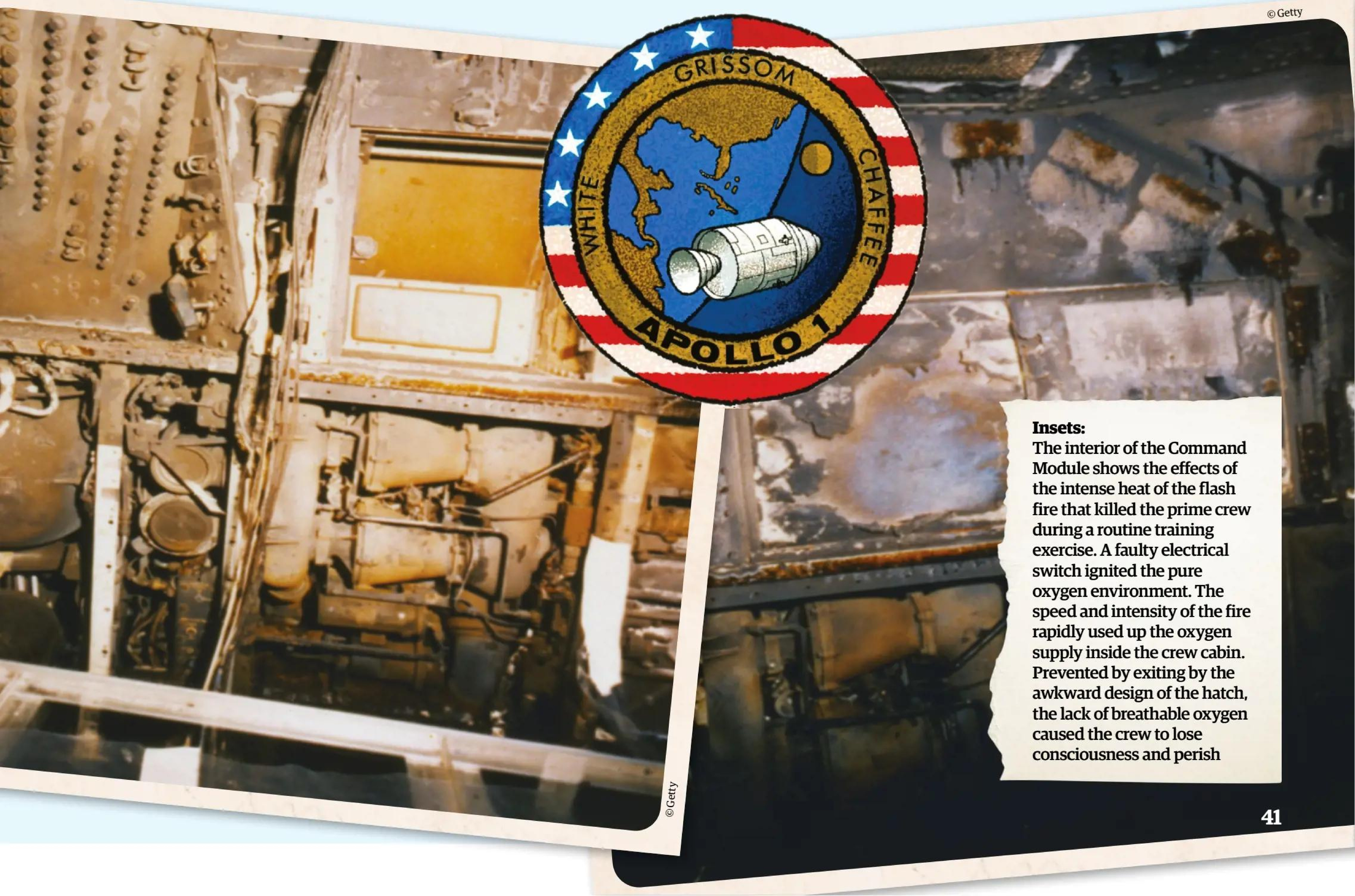
> "They gave their lives in service to their country in the ongoing exploration of humankind's final frontier"



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Insets:
The interior of the Command Module shows the effects of the intense heat of the flash fire that killed the prime crew during a routine training exercise. A faulty electrical switch ignited the pure oxygen environment. The speed and intensity of the fire rapidly used up the oxygen supply inside the crew cabin. Prevented by exiting by the awkward design of the hatch, the lack of breathable oxygen caused the crew to lose consciousness and perish

going to get to the Moon if we can't talk between two or three buildings?"

With communications problems dragging on, the practice countdown was held. Then at 6.31pm came a frightening word from the spacecraft: "Fire."

Deke Slayton, who oversaw crew selections at NASA and was present for the test, could see white flames in a closed-circuit television monitor pointing toward the spacecraft. The crew struggled to get out. Technicians raced to the scene, trying to fight the fire with extinguishers amid faulty breathing masks.

At last, the door was open, but it was too late.

The aftermath and changes

A NASA review board found a stray spark (probably from damaged wires near Grissom's couch) started the fire in the pure oxygen environment. Fed by flammable features such as nylon netting and foam pads, the blaze quickly spread. Further, the hatch door – intended to keep the astronauts and the atmosphere securely inside the spacecraft – turned out to be too tough to open under the unfortunate circumstances. The astronauts had struggled in vain to open the door during the fire, but the pressure inside the spacecraft sealed the door and made it impossible to open. The board listed a damning set of circumstances, failures and recommendations for future spacecraft designers to consider.

The US Senate conducted its own investigation and hearings and published recommendations of its own, while saying NASA's failure to report its problems with Apollo "was an unquestionably serious dereliction."

Several changes were made to the design of the Apollo spacecraft to improve crew safety. The flammable oxygen environment for ground tests was replaced with a nitrogen-oxygen mix. Flammable items were removed. A new respect developed between the astronauts and the contractors concerning design changes, which were implemented more effectively. Most notably, the hatch door was completely redesigned so that it would open in mere seconds when the crew needed to get out in a hurry.

Decades later, NASA recalls the Apollo 1 incident every January during an annual Day of Remembrance. It also honours the Challenger and Columbia crews, who died in 1986 and 2003, respectively. Further, an exhibit honouring the Apollo 1 crew was opened at the Kennedy Space Center in 2017, displaying the hatches that were on the spacecraft. The exhibit was planned in consultation with the astronauts' families.

> "Remember them not for how they died but for those ideals for which they lived"
> **Memorial plaque at Cape Canaveral**

NASA
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NASA
WHITE

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V.I. GRISSOM
M.S.C. N.A.S.A
NASA
R. CHAFFEE
M.S.C. NASA
NASA
UNITED
STATES

> “In memory of those who made the ultimate sacrifice so others could reach for the stars. Ad astra per aspera (a rough road leads to the stars). God speed to the crew of Apollo 1”
>
> **Memorial plaque at Cape Canaveral**

Main:
Ed White (left) had performed the US’s first spacewalk in 1965 and Gus Grissom (centre) was the first US astronaut to make perform two flights. Apollo 1 was due to be Roger Chaffee’s (right) first spaceflight

Left:
Chaffee, Grissom and White, pictured during training inspecting spacecraft equipment

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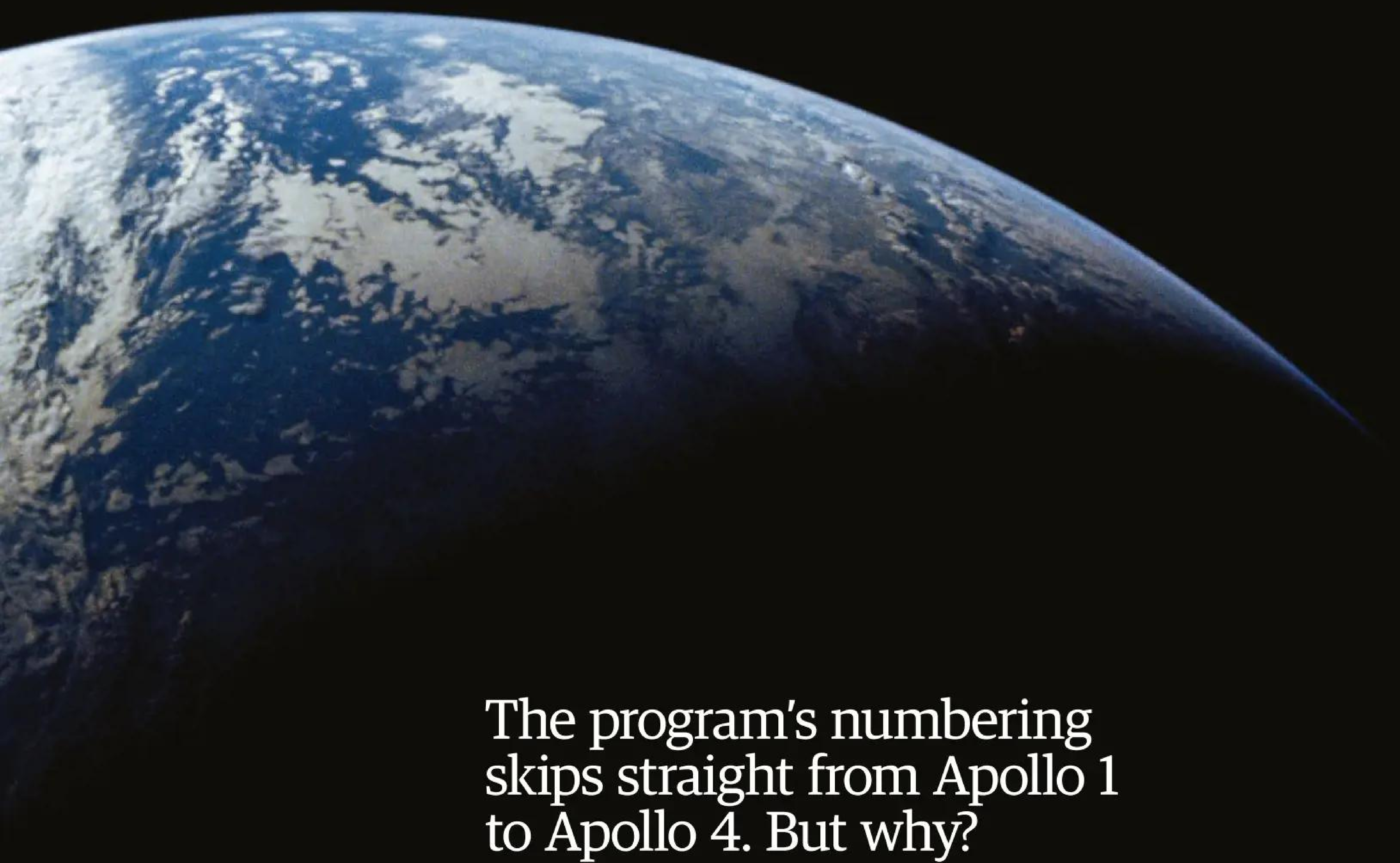

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The program's numbering skips straight from Apollo 1 to Apollo 4. But why?

The lost APOLLO MISSIONS

Reported by Jonathan O'Callaghan

NASA's original plan to send humans to the Moon was daring, if not risky. Two uncrewed flights of the Saturn rocket would be followed by three crewed flights. Then there would be a lunar landing rehearsal, followed by the actual landing – just the seventh mission of the Apollo programme. And in 1966, things were looking pretty good. The agency's Gemini missions were ticking along nicely, with about half of them complete. Early variants of the Saturn rocket had been tested, and components of the Apollo missions were far through in development. What could go wrong?

The Apollo missions, before they were numbered, were designated by a letter. The initial missions in Earth orbit would begin with the 'A mission', which would be an uncrewed flight of the command-service module (CSM) that would house the astronauts to and from the Moon. The B mission would test the lunar module (LM) itself on an uncrewed flight, followed by the first crewed flight of the Apollo programme using the CSM, dubbed the C mission. Then there would be a crewed flight using both the CSM and the LM, the D mission. Then the E mission would travel to a higher orbit, to test high-speed re-entry through Earth's atmosphere. The F mission would be the first crewed mission to the Moon, practicing a lunar landing. And the G mission would ultimately be the first attempt at a landing.

It's worth noting that the C and D missions, which would be Apollo 1 and 2, were originally scheduled to be identical missions flying the CSM. The goal would have been just to make sure that everything worked as planned – going to the Moon was high-risk after all. But NASA had tried to avoid duplicating missions to save time, so the LM was eventually added to the Apollo 2 mission so that it would be sufficiently different. Delays to the CSM for the Apollo 2 mission also meant this decision made more sense, so they could essentially skip a wasted mission. Apollo 3 would then be the re-entry from a high orbit, before the Apollo 4 mission went to the Moon for the first time, and the Apollo 5 mission landed on the surface.

Based on this plan, the first humans to travel to the Moon on the Apollo 11 mission would not have been Neil Armstrong, Buzz Aldrin and Michael Collins. Instead it might have been Pete Conrad, Dick Gordan and Clifton Williams. However it also seemed possible that Gus Grissom, who became the second American to go to space in 1961, might instead have been the commander on the first mission – and thus would have been the first person to walk on the Moon. That appeared to be the preference from Deke Slayton, who was the Director of Flight Crew Operations at NASA from 1962 to 1972 and thus in charge of deciding who went on which flight.

But on 27 January 1967, everything changed. On that day, NASA was conducting a test of the Apollo 1 spacecraft, the first crewed flight of the Apollo programme. This would see Gus Grissom, Ed White and Roger Chaffee travel to Earth orbit, before returning to the ground. The plan was to launch on 21 February 1967 – the test in January was a "plugs out" test, with the crew inside the spacecraft

Left: This was the launch of AS-201, which was the first flight of an Apollo spacecraft

Left below: The Apollo 1 disaster caused a complete reshuffle and delay of the Apollo programme

Right: Wally Schirra on the Apollo 7 mission in 1968, which became the program's first crewed mission

© NASA

to check if it could operate on its own power. But during the test, a spark inside the spacecraft ignited its pure oxygen atmosphere. The entire interior of the spacecraft burst into flames, and within a minute, all three astronauts were dead.

The Apollo 1 disaster caused a complete rethink of the Apollo programme. First there was an investigation into the accident, which found problems with the way NASA was managing the project, along with some problems with the spacecraft itself. The program was grounded while the cause of the fire was investigated, concluding in April 1967. The CSM used in Apollo 1 was called Block I, the first iteration of the vehicle. It was decided to use the remaining Block I's for uncrewed test flights, with the crewed flights to use the newer Block II vehicle, which addressed a number of concerns. This included changing the atmosphere inside the cabin from pure oxygen to a mixture of 60 percent oxygen and 40 percent nitrogen, and removing flammable materials from the cabin.

The accident also resulted in a complete reshuffle of the Apollo missions. The first major change was that the widows of the three astronauts ask that the Apollo 1 name itself be retired, a change that was agreed to. Three uncrewed Apollo missions had already occurred by this point, although only two of them carried spacecraft. So the decision was made to start missions again from Apollo 4, which launched on 9 November 1967. This was the first flight of the Saturn V vehicle itself, with a Block I CSM vehicle on board, and also the first flight from a launch pad called Launch Complex 39 at the Kennedy Space Center in Florida, which would ultimately become the spot where humans launched to the Moon from.

This reshuffling of the missions meant that Apollo 5, also an uncrewed mission, became a variant of the original B mission. It launched on 22 January 1968, and carried the LM into Earth orbit. Here the spacecraft tested out its descent engines, which were needed to actually land on the surface of the Moon. There was also no CSM on board the vehicle, which was a Saturn 1B - an earlier version of the Saturn rocket, and not as big or powerful as the full Saturn V. Then came the Apollo 6 mission, which launched on 4 April 1968. This was the second flight of the Saturn V vehicle, and was intended to place the CSM and LM on a path towards the Moon - although it would not actually travel to the Moon itself, it was just proving it could be done. There were some problems with the rockets engines, however, but NASA concluded the test was a success overall. The Apollo programme could continue.

That, of course, led directly to the first crewed flight of the Apollo programme - the Apollo 7 mission on 11 October 1968 with Wally Schirra, Donn Eisele and Walter Cunningham on board. The mission, which took place on a Saturn 1B rocket, was passed with flying colours; the three astronauts tested the CSM in Earth orbit before returning to Earth. Apollo 8, 9 and 10 would all take humans to lunar orbit from December 1968 to May 1969, before that fateful Apollo 11 mission in July 1969. The rest, as they say, is history.

Apollo 2 and 3

Following the Apollo 1 disaster, that mission designation was retired in its honour. Apollo 2 and 3, however, were a different story. Originally they were intended to be uncrewed tests of the Saturn rocket and the lunar spacecraft, but the reshuffle of the missions following the Apollo 1 fire caused a change. NASA had already performed three uncrewed test flights for the Apollo programme in 1966, which were three flights of the Saturn 1B rocket. They were called AS-201, AS-203 and AS-202. Only 201 and 202 carried a spacecraft though, testing how the CSM performed in space and checking if it could re-enter the atmosphere safely. So when NASA redesignated the Apollo missions, it decided to unofficially refer to these as Apollo 2 and 3. The first uncrewed flight of the Saturn V in November 1967 became Apollo 4, and from that the missions continued to sequentially increase up to the final mission, Apollo 17 in 1972.

Right: **If the Apollo 1 tragedy never occurred, Gus Grissom (pictured) may have become the first human to walk on the Moon**

NASA
EISELE
SCHIRRA

The crew of Apollo 7 posing for an official portrait in their suits

How the first successful test of both spacecraft and crew paved the way to the Moon

APOLLO 7

"We have lift-off"

Reported by Elizabeth Howell

© NASA JSC

Apollo 7 was the programme's first successful crewed flight into space. The crew of Wally Schirra, Don Eisele and Walter Cunningham spent nearly 11 days in space as they orbited Earth and tested out the spacecraft that was designed to bring humans safely to the Moon and back again.

By the time the mission launched on 11 October 1968, NASA had worked hard at improving crew safety and heeded the concerns that arose after a Command Module fire killed the Apollo 1 crew 20 months earlier during a routine launch pad test. But Apollo 7 proved to be an engineering success, despite crew illness and reports of tension between the space crew and ground crew.

Apollo 7 was essentially a test flight for manned spacecraft. After Apollo 1, three unmanned launches – designated Apollo 4, 5 and 6 – had tested the Saturn rockets, the Lunar Module and the Command Module. No missions or flights were ever designated Apollo 2 or 3.

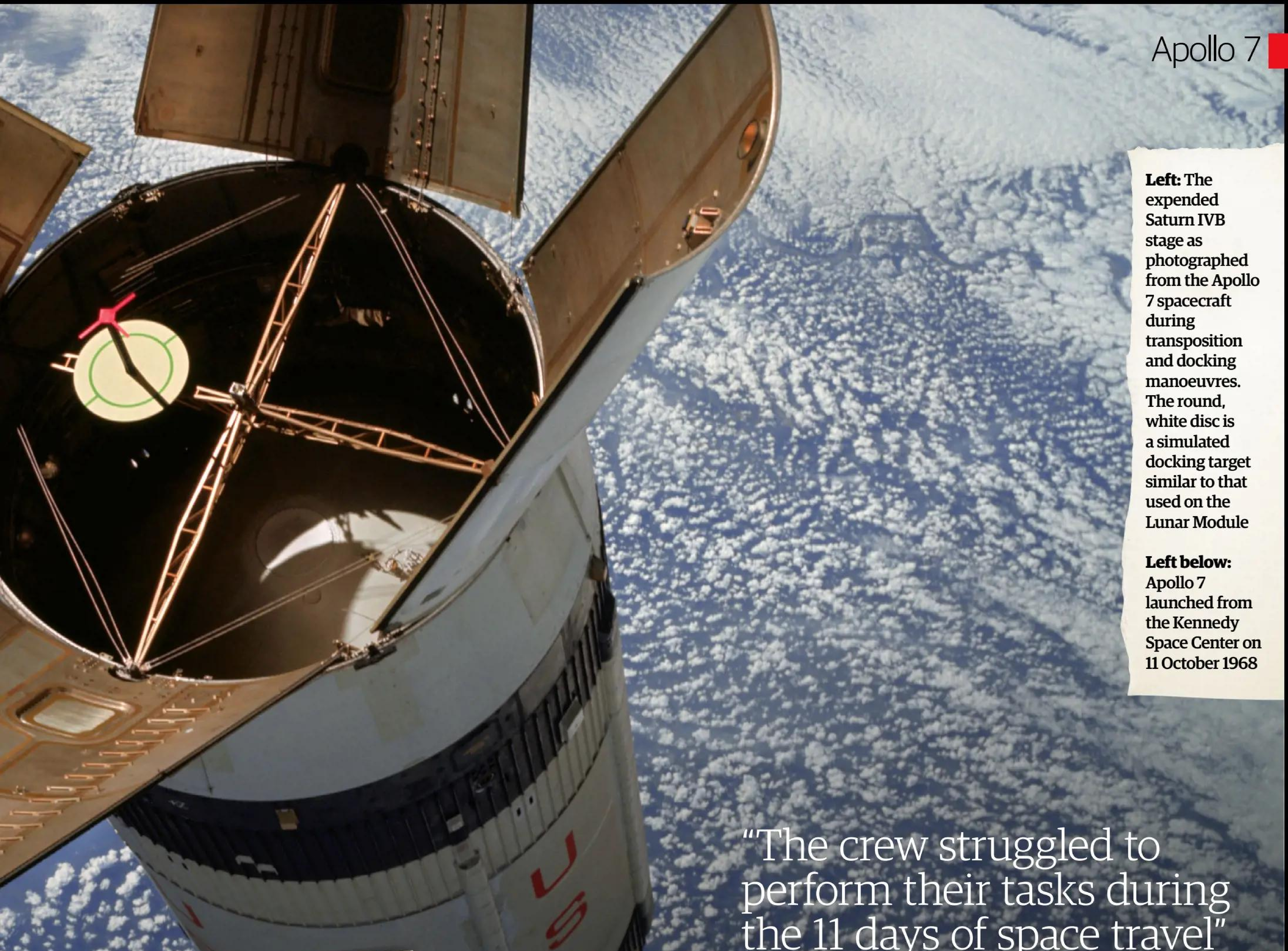
Commanding the Apollo 7 crew was Wally Schirra, a veteran of NASA's Mercury programme, which was the first human spaceflight programme at NASA. Schirra was the fifth American in space and flew a mission called Sigma 7 on 3 October 1962, circling six times around the Earth. Schirra was also part of the Gemini programme that had two crews of two people fly into space simultaneously. He commanded the Gemini 6

The crew

Below: **The crew of Apollo 7, pictured following their return to Earth. From left to right: Commander Walter Schirra, Command Module pilot Donn Eisele, and Lunar Module pilot Walter Cunningham**

NASA
D. F. EISELE
CUNNINGHAM

VII
SCHIRRA · EISELE · CUNNINGHAM

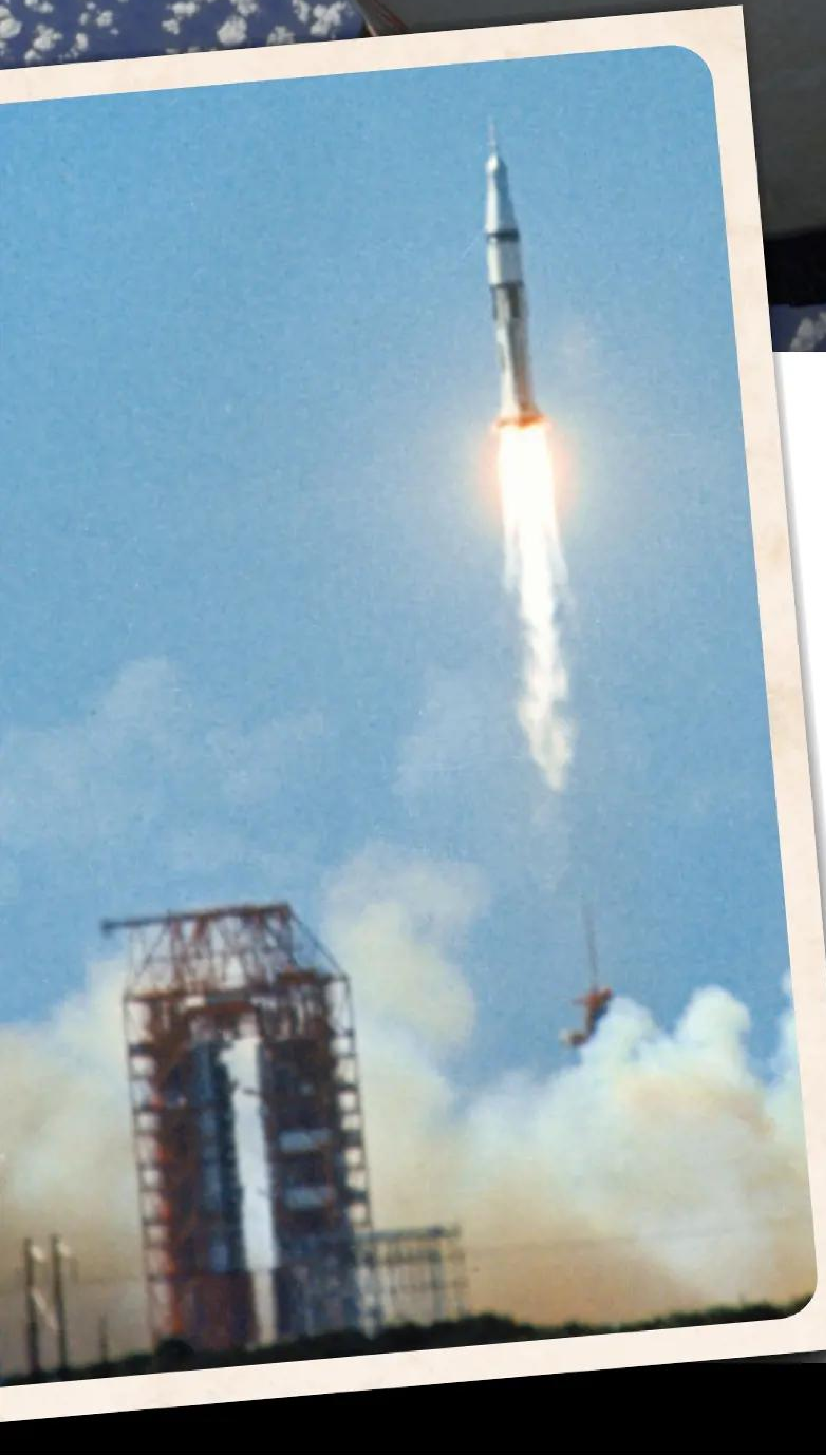


Left: The expended Saturn IVB stage as photographed from the Apollo 7 spacecraft during transposition and docking manoeuvres. The round, white disc is a simulated docking target similar to that used on the Lunar Module

Left below: Apollo 7 launched from the Kennedy Space Center on 11 October 1968

> "The crew struggled to perform their tasks during the 11 days of space travel"

© All Images: NASA JSC



mission, which (along with Gemini 7) performed the first rendezvous between two manned spacecraft. Schirra was the only astronaut who flew in the Mercury, Gemini and Apollo programmes.

With Schirra were two spaceflight rookies. Walter Cunningham was a Navy pilot who previously to joining NASA had worked on classified defence studies as a scientist for the Rand Corporation. Meanwhile, Donn Eisele was an Air Force test pilot who had previously worked on special weapons development projects.

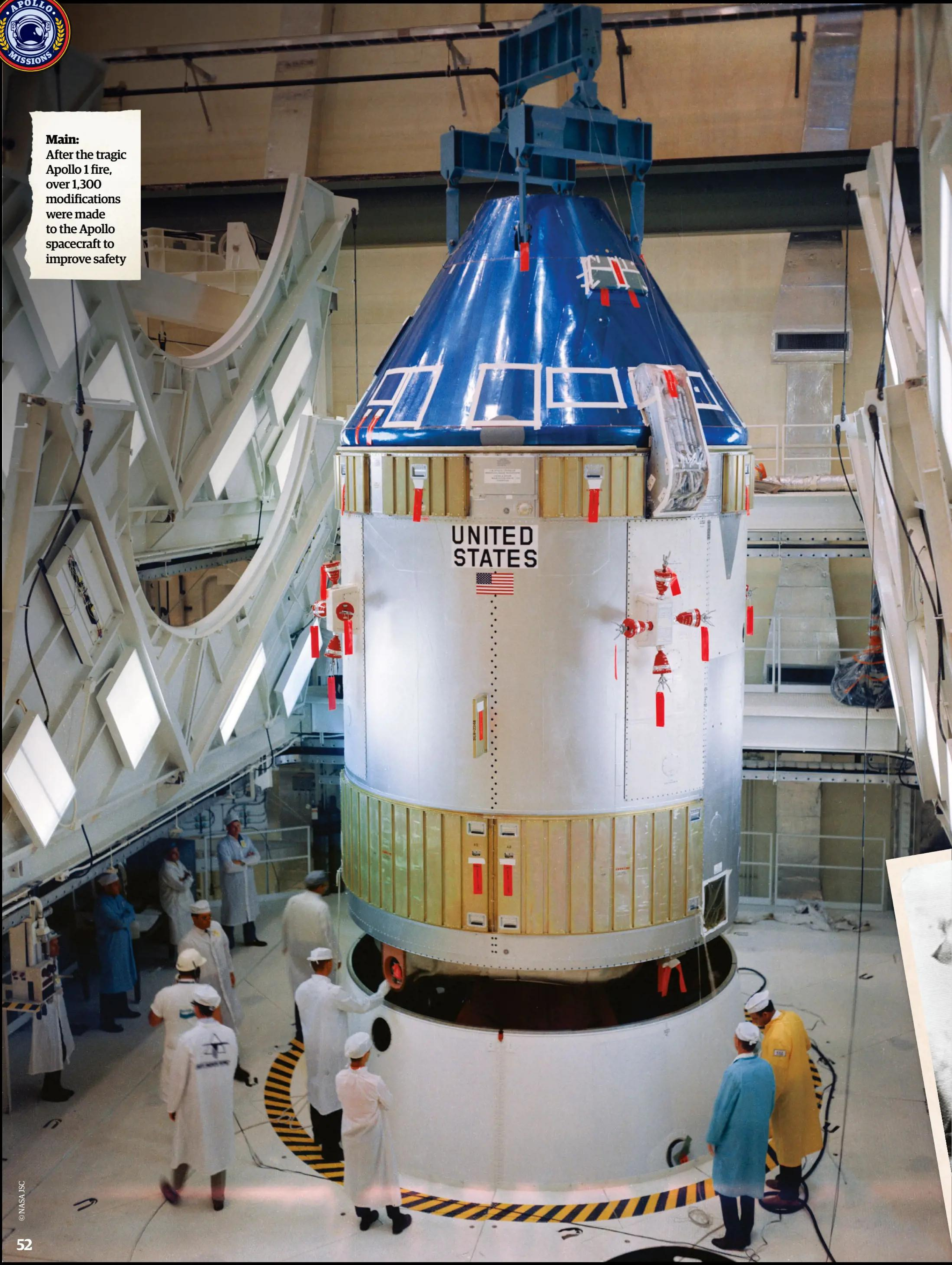
'Yabba Dabba Doo'

After they had completed a couple of Earth orbits, Schirra turned the Command Module around to simulate a docking with the third stage of the Saturn IB rocket, called Saturn IVB. Future Moon missions would require dockings between two spacecraft, the command and Lunar Modules, so the manoeuvre was important practice.

The crew also tested out the Command Module engine extensively. This engine had to work flawlessly for the upcoming Moon missions. It was designed to bring crews to the Moon, slow the spacecraft down to enter lunar orbit, speed the spacecraft up to exit lunar orbit, and then position the crew for a safe re-entry back to Earth.

In NASA parlance, the engine had eight "nearly perfect firings" in the eight times the crew turned it on and off. The engine gave a powerful jolt to the spacecraft the first time it fired, slightly startling the crew. Schirra, feeling the vibration, yelled "Yabba Dabba Doo!" This was the catchphrase for Fred Flintstone, a popular cartoon character from the animated 1960s sitcom *The Flintstones*.

While the mission in large part was a success, there were a few engineering glitches aboard the Command Module. The windows fogged, making visibility poor (but not impossible) for the astronauts inside. Also, there were minor problems



Main: After the tragic Apollo 1 fire, over 1,300 modifications were made to the Apollo spacecraft to improve safety

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in the electrical and fuel cell systems, and - in the crew's opinion - overly noisy cooling fans inside the cabin. All of these issues were noted so they could be fixed prior to future missions.

Controversial crew performance

An Apollo spacecraft was cramped quarters under the best of circumstances. On Apollo 7, the crew immediately learned of one of the drawbacks: it was very easy to catch an illness.

Schirra came down with a cold only 15 hours after launch, according to NASA, and passed along the illness to Cunningham and Eisele. Accounts differ on the severity of their colds.

In the microgravity environment of space, fluids don't drain as they do on Earth. This meant blocked ears and noses for the crew, who tried - with little success - to alleviate the symptoms by taking medication. The crew struggled to perform their tasks during the 11 days of space travel. Biographical accounts from astronauts and mission controllers affiliated with Apollo 7 said the crew was frequently cranky when talking to ground controllers. However, the description varies depending on who's telling the story.

Multiple biographies say that Schirra became so frustrated he pulled the plug on one of the television broadcasts. Eisele also complained about one test the crew performed, saying he wanted to speak to the person who "thought up that little gem." That person turned out to be a high-ranking NASA official: respected Mission Control flight director Glynn Lunney.

Just before re-entry, the crew elected not to wear their suit helmets; they were concerned about pressure hurting their ears as they arrived on Earth, and wanted the chance to blow their noses to relieve the pressure. This drew the ire of some at NASA. "It was insubordinate [...] This crew shouldn't fly again," wrote flight director Christopher Kraft in his 2001 memoir, *Flight: My Life in Mission Control*.

In his own 2000 biography, *Schirra's Space*, Schirra said the disagreements between flight crew and ground crew boiled down to one thing: "I was convinced that the men in Houston were overlooking certain intangible things," he wrote.

While not elaborating on what those things were, he added that the crew had worked with the spacecraft for three years and knew its capabilities.

Conflict aside, the Apollo 7 mission was an engineering success. The programme was ready to move on to the next phase: targeting the Moon.

Apollo 7 legacy

The current location of the Apollo 7 spacecraft is at the Frontiers of Flight Museum in Dallas, where Cunningham was a long-standing board member. This year marks the 50th anniversary of Apollo 7.

While Apollo 7 is not as well-remembered as other Apollo missions that reached the Moon, it was an essential engineering test to prove the performance of the Command Module. NASA's next mission, Apollo 8, sent three astronauts in a Command Module directly to the Moon for a lunar-orbiting mission. It was a daring mission that would have been far riskier without the Apollo 7 tests.

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Top: Walter Cunningham pictured aboard Apollo 7. The relatively long mission and cramped conditions of the capsule led to some tensions between the crew and Mission Control

Middle: The crew's view of the sunrise over the Gulf of Mexico, taken during the spacecraft's 134th orbit of the Earth

KEEP THOSE
CARDS AND LETTERS
COMING IN
FOLKS

© NASA JSC

Left: The crew held the first live television broadcast from space during their mission

Just two months after the first manned Earth-orbit tests, Project Apollo made an ambitious leap

APOLLO 8

First flight to the Moon

Reported by Elizabeth Howell

BORMAN LOVELL ANDERS
USA

© NASA; SpoonGraphics

Apollo 8 was the second crewed mission of the Apollo program and the first mission to bring humans to the Moon. The six-day mission lifted off on 21 December 1968, with its crew of Frank Borman, Jim Lovell and Bill Anders. The flight included a day orbiting the Moon, during which the astronauts took the "Earthrise" picture – one of the most iconic photographs ever taken of our planet. The photo has also been credited as a major impetus for the environmental movement.

This historic mission happened because of a last-minute decision from NASA management. Initially, the agency planned to test the Lunar and Command Module components of the Apollo spacecraft first before striking out for the Moon. At the time, the United States and Russia were engaged in a "space race," endeavoring to demonstrate their technological prestige in space exploration. And NASA – while keeping crew safety in mind – wanted to take the necessary steps to bring Americans to the Moon as soon as possible. But sending Apollo 8 to lunar orbit after only one previous Apollo mission, which had remained in Earth orbit, was a difficult decision.

"NASA officials realized that this was risky, since Apollo 7 had not yet qualified the spacecraft when their tentative decision was made," a NASA historical document reported. The decision was further complicated by Apollo 8's need for a more powerful rocket, called the Saturn V, which had never been tested on a crewed launch. But after months of discussion, NASA decided to move forward with an Apollo 8 Moon mission on 10 November, about a month before the launch.

Spacecraft commander Borman and crewmember Lovell were also crewmates on the Gemini 7 mission, which aimed to test endurance. They spent nearly 14 days living together in a small spacecraft. Borman had also distinguished himself by serving on a review board investigating the Apollo 1 fatal fire in 1967.

The mission's third crewmember, Anders, was a former fighter pilot in the U.S. Air Force. He hadn't flown in space before but had served as a backup crewmember for Gemini 11.

Across the Atlantic and the lunar gulf

The night before launch, aviation pioneer Charles Lindbergh paid a visit to the Apollo 8 crew. Lindbergh, whose nickname was "Lucky Lindy," was the first person to fly solo over the Atlantic Ocean, which he'd done 41 years before. He asked how much fuel they would need to get into space, according to Robert Zimmerman's account in his

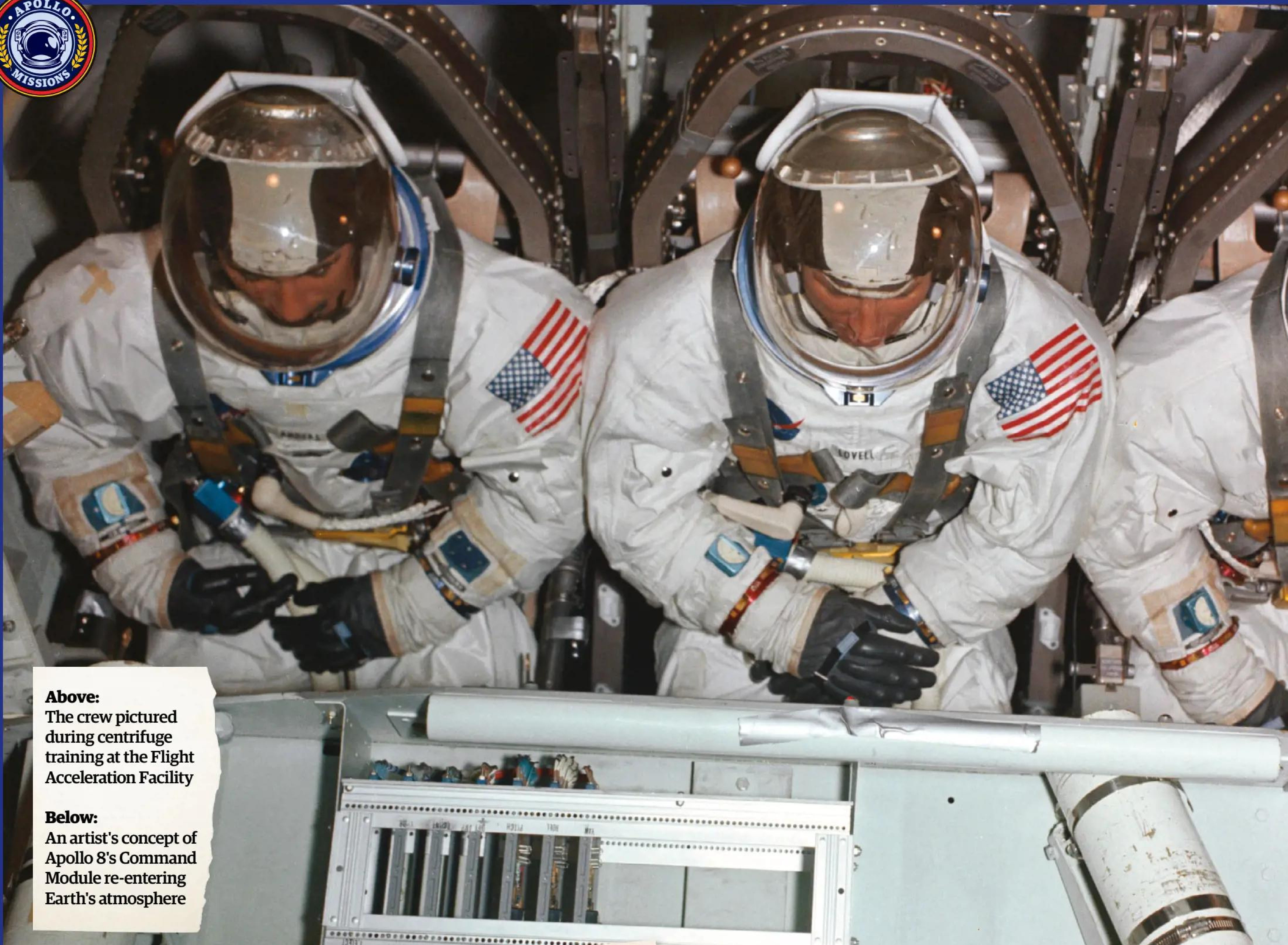
"Sending Apollo 8 to lunar orbit after only one previous mission, which had remained in Earth orbit, was a difficult decision"

Above inset: The mission was the first crewed launch of the Saturn V rocket

Left: The crew make their way to Launch Pad 39 on the morning of 21 December 1968. Left to right are Anders, Lovell (waving) and Borman

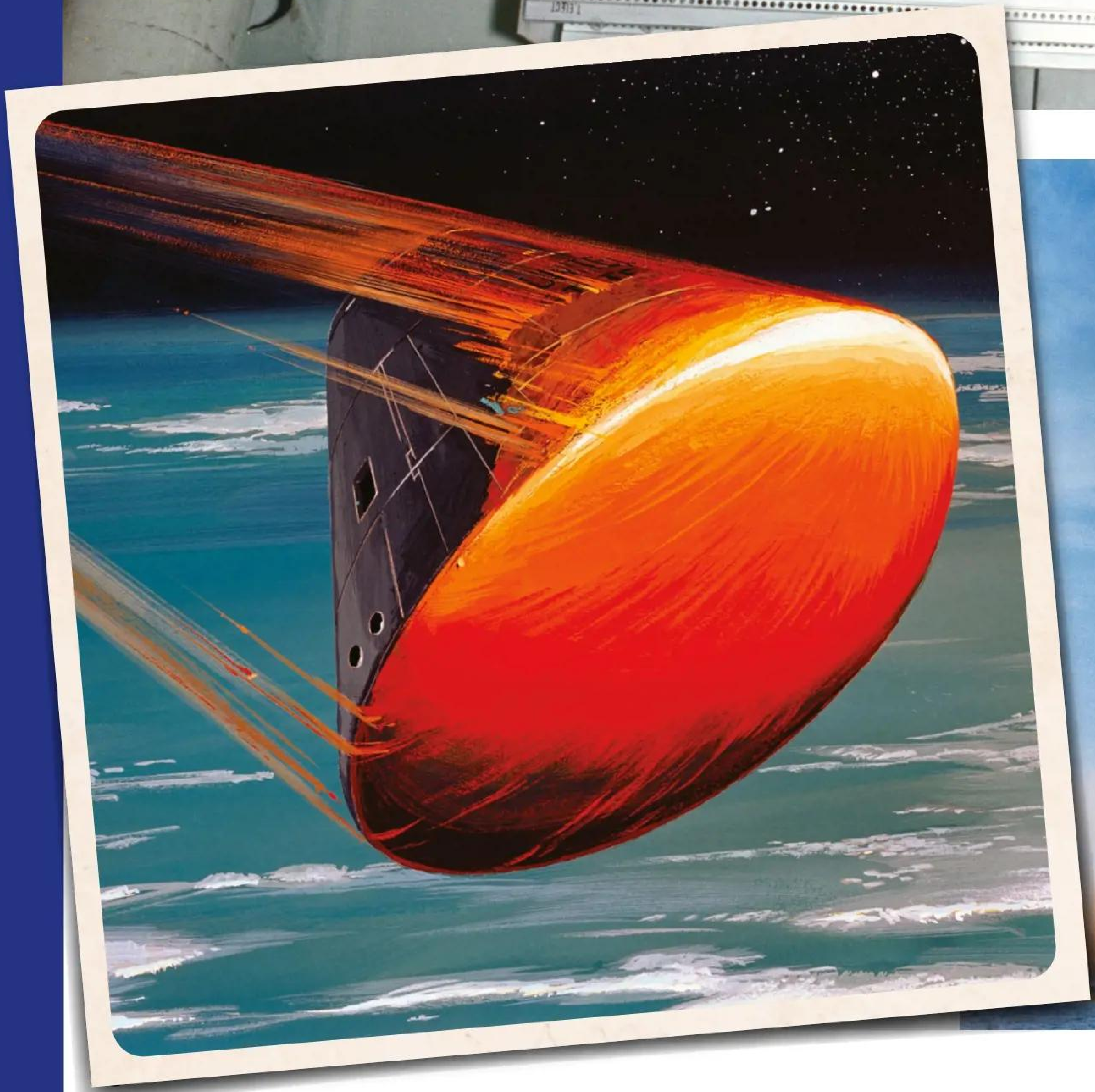
Main: The Apollo 8 crew, from left to right: Commander Frank Borman, Lunar Module pilot William Anders, and Command Module pilot James Lovell

© images: NASA



Above:
The crew pictured during centrifuge training at the Flight Acceleration Facility

Below:
An artist's concept of Apollo 8's Command Module re-entering Earth's atmosphere



Below:
On 21 December 1968, NASA launched the first humans to the Moon

book "Genesis: The Story of Apollo 8" (Dell, 1999). When Lindbergh heard that the rocket would consume 20 tons of fuel a second, he smiled and said, "In the first second of your flight tomorrow, you'll burn ten times more fuel than I did all the way to Paris."

As expected, Apollo 8's journey across the Atlantic Ocean took only minutes. The crew were the first astronauts to be launched into space by the Saturn V rocket. After settling into orbit around Earth, they performed their final checks and received the "go" from NASA for trans-lunar injection. This meant they were clear to fire their engines and aim for the Moon.

Just 18 hours after launch, Apollo 8 experienced a major problem: Borman fell ill and struggled through vomiting and diarrhea. The commander felt better after getting some sleep, but as a precaution, the other crewmembers radioed to Earth on a private channel and explained Borman's predicament. NASA performed a private medical consultation for Borman. When hearing that Borman's health had improved, NASA cautiously gave the approval to continue with the mission.

Christmas Eve at the Moon

Placing the Apollo spacecraft in lunar orbit was not easy. Compounding the difficulty, the engine firing, which would put the spacecraft in the right spot, had to happen while the spacecraft was out of contact with Earth, on the far side of the Moon. But the crew remained focused, and Apollo 8 made it into lunar orbit right on schedule.

On Christmas Eve, the crew had the chance to share their impressions with others via a public broadcast. Borman called the Moon a "vast, lonely, forbidding type of existence," while Lovell paid tribute to the Earth's "grand ovation to the vastness of space." The crew also read a passage from Genesis, the first book of the Bible.

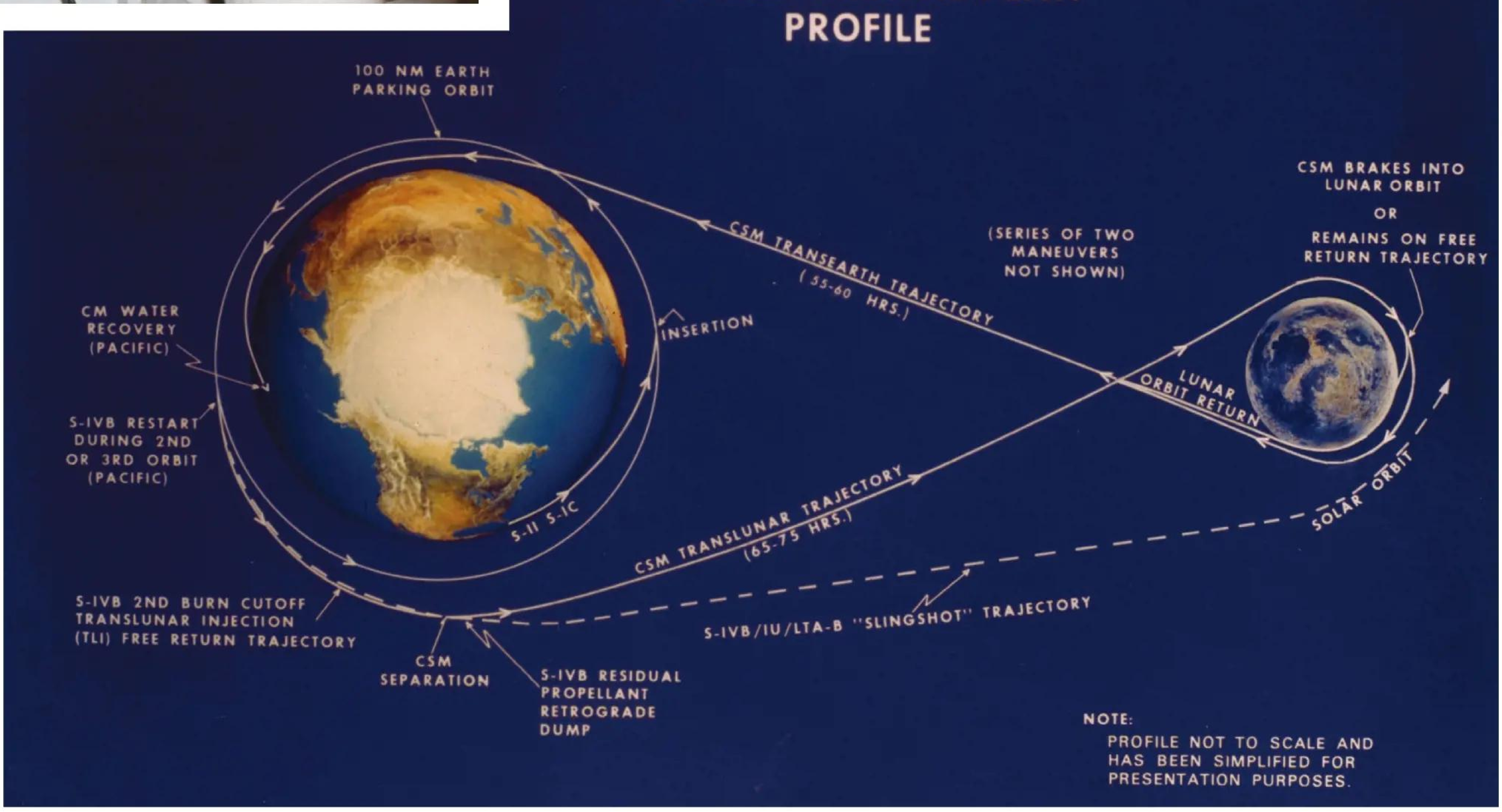
All that remained was the return trip home. Mission controllers waited anxiously Christmas morning as the crew turned their engine on again, on the far side of the Moon.

As they re-emerged, Lovell called out, "Please be informed, there is a Santa Claus," signaling that the ship was headed back to Earth. The crew landed successfully on 27 December.

Legacy of Apollo 8

The Apollo 8 spacecraft is on display at the Chicago Museum of Science and Industry. This craft showed that Apollo could safely bring humans to the Moon; the next major task would be learning how to land on the lunar surface.

After Apollo 8, the Apollo 10 mission brought the lunar lander to within 15,200 meters (50,000 feet) of the Moon's surface, to simulate a landing. Then, in 1969, Apollo 11 safely landed the first people on the Moon. NASA sent several other missions to the Moon, with five landing successfully (Apollo 12, and Apollos 14 through 17).


APOLLO 8
LUNAR ORBITAL PLAN
PROFILE
100 NM EARTH PARKING ORBIT
CSM BRAKES INTO LUNAR ORBIT
OR
REMAINS ON FREE RETURN TRAJECTORY
(SERIES OF TWO MANEUVERS NOT SHOWN)
CSM TRANSEARTH TRAJECTORY (55-60 HRS.)
INSERTION
CM WATER RECOVERY (PACIFIC)
LUNAR ORBIT RETURN
S-IVB RESTART DURING 2ND OR 3RD ORBIT (PACIFIC)
S-II S-IC
CSM TRANSLUNAR TRAJECTORY (65-75 HRS.)
SOLAR ORBIT
S-IVB 2ND BURN CUTOFF TRANSLUNAR INJECTION (TLI) FREE RETURN TRAJECTORY
S-IVB/IU/LTA-B "SLINGSHOT" TRAJECTORY
CSM SEPARATION
S-IVB RESIDUAL PROPELLANT RETROGRADE DUMP
NOTE:
PROFILE NOT TO SCALE AND HAS BEEN SIMPLIFIED FOR PRESENTATION PURPOSES.

© Images: NASA

The Lunar Module's debut

APOLLO 9

The Earth-orbiting mission that tested vital equipment and paved the way for humankind's first step onto the Moon

Reported by Lee Cavendish

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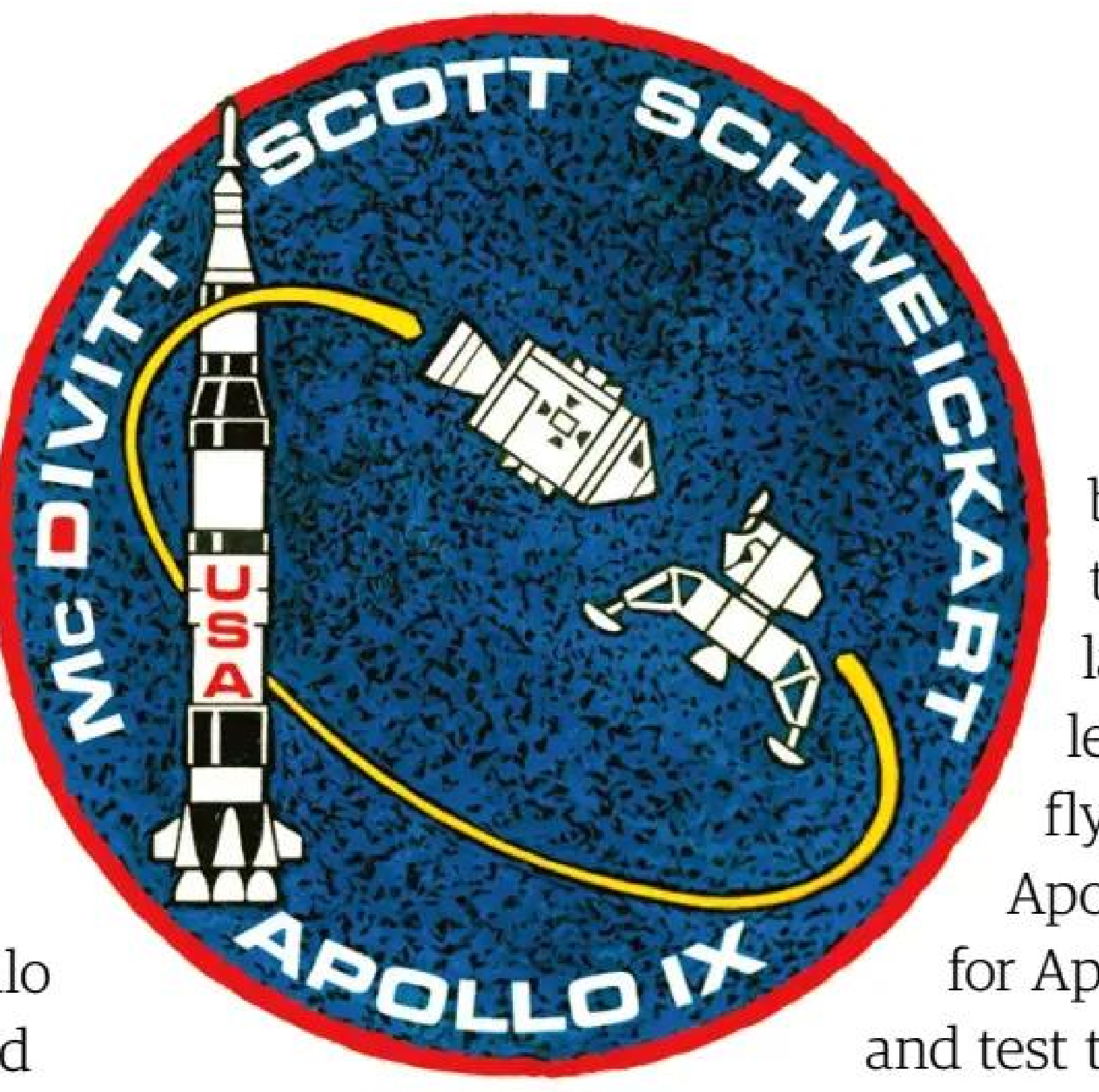


The Apollo program paved the way for human space exploration and inspired a generation of future astronauts, scientists and engineers. Apollo 11, the mission that saw Neil Armstrong and Buzz Aldrin step foot on the Moon, wasn't possible without the ten other missions before it.

2019 marks the 50th anniversary of the Apollo 9 mission that saw James A McDivitt, David R Scott and Russell "Rusty" Schweickart conduct the first tests of the crewed Lunar Module (LM) and Command and Service Module (CSM) along with the portable life-support systems that would be used when exploring the Moon.

On 3 March 1969 these three astronauts strapped themselves in for the ride of their lives, sitting aboard a Saturn V rocket at NASA's John F. Kennedy Space Center in Florida, United States. This mission was only the second crewed mission to launch on a Saturn V rocket, and the third crewed mission in the United States' Apollo program. For the next 241 hours and 54 seconds the Apollo 9 crew would experience the wonders of space while performing their duties as professionals to ensure for a successful trip. But what if they weren't even supposed to be there?

This was almost the case, as McDivitt, Scott and Schweickart were all actually supposed to be on the earlier Apollo 8 mission – the mission that circled the Earth in December 1968. "Those were very complicated times and the mission shifted all over. We were actually the backup crew for the first Apollo missions, including Apollo 7, but we were also going to pick up the Lunar Module and be the first to fly it," Schweickart told **All About Space**. "Then we were shifted off the backup crew and [Walter] Wally Schirra's team took our places for the first Apollo mission, with Gus Grissom, Roger Chaffee and Ed White the appointed first-choice crew. We moved into a totally different mission, but we were going to fly the Lunar Module. Then that didn't work and Frank Borman proposed moving his flight."

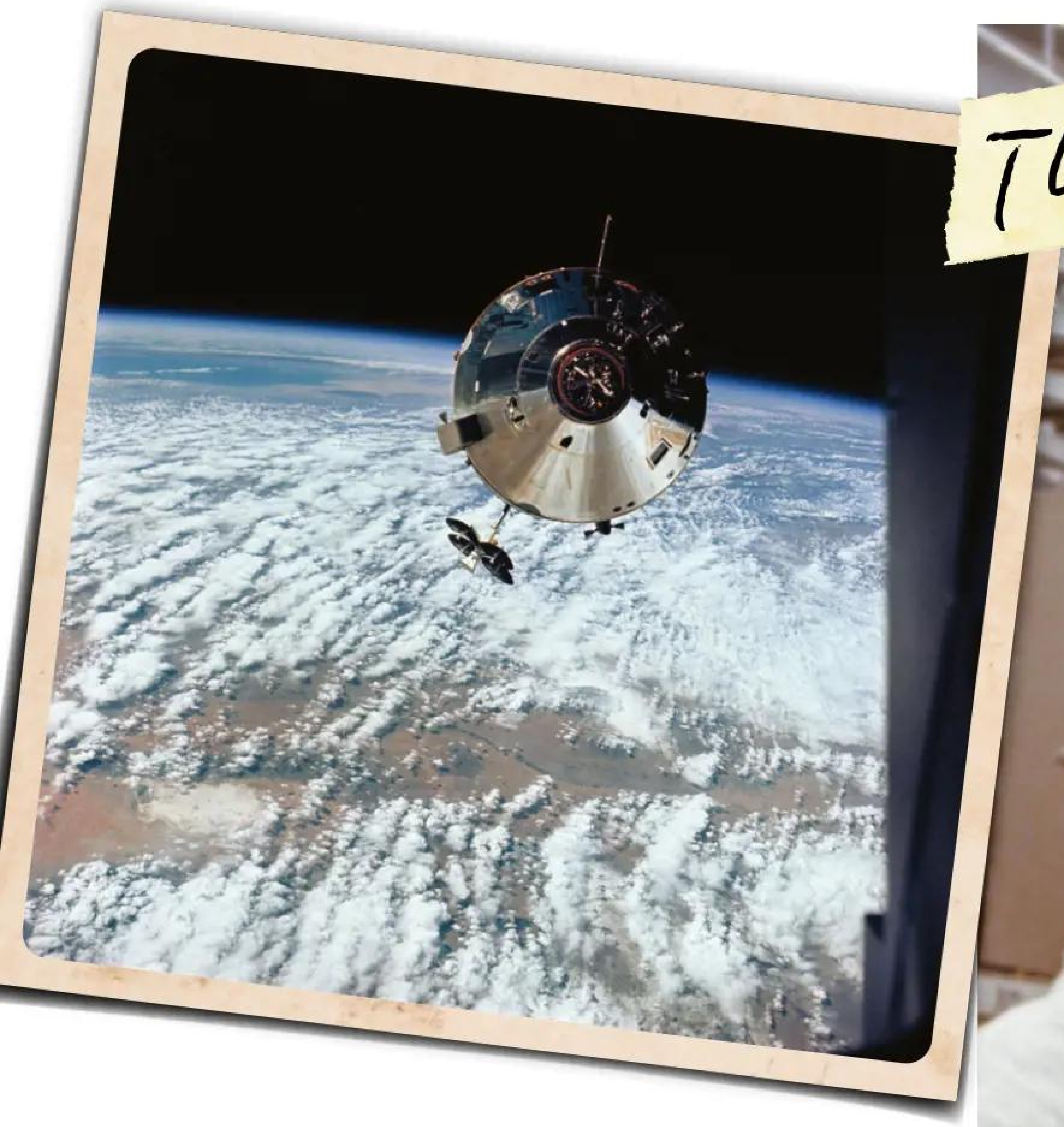
Each prime crew had a backup crew who would fly as the prime crew three missions later, and it was this rule that led to Armstrong and his crew flying as the prime crew on Apollo 11. But they had to wait. As for Apollo 9, it had to reach space and test the technologies that NASA had been improving in its laboratories. Each crew member was selected from the astronaut group of either 1962 or 1963. The Commander, McDivitt, had been the Command pilot for Gemini 4, and his backup was Charles "Pete" Conrad Jr. The Lunar Module pilot, Schweickart, was making his first spaceflight, with his backup being Alan Bean, and Command Module pilot Scott had experience as a pilot of Gemini 8; his backup was Richard "Dick" Gordon. This backup crew served as the prime crew for the Apollo 12 mission.

After the initial ascent it was time to test the docking between the unmanned LM, which was given the nickname Spider, still attached to the third stage of the Saturn V rocket, and the CSM, which was given the nickname Gumdrop. During the second orbit of Earth the two modules docked before jettisoning the remainder of the Saturn V rocket. This was the first hurdle to overcome before what would turn out to be an extremely fruitful ten days in space.

> "You don't get in a suit and go outside in space if you're going to have motion sickness – that will kill you" **Rusty Schweickart**

Above: Rusty Schweickart was the first to test the Apollo extravehicular mobility unit

Right: Apollo 9's launch on 3 March 1969



On the third day of flight, McDivitt and Schweickart suited up in a new-and-improved design based on the Gemini days and prepared to board Spider. During this time on board the LM they conducted systems checks and fired the module's descent rockets to simulate the throttle pattern that would be used during a lunar-landing mission. During this time Schweickart wasn't feeling too great due to the nausea he was experiencing. In fact, Commander McDivitt had reported that he had vomited on two occasions.

This nausea comes from the effects of weightlessness on the organs of balance in the inner ear. With these organs not functioning properly under the effects of gravity, astronauts can become susceptible to space sickness. The Lunar Module pilot's nausea pushed back some of the crew's operations, including the first Apollo extravehicular activity (EVA). "We had to postpone the EVA because I had motion sickness the day before, and you don't get in a suit and go outside in space if you're going to have motion sickness, because that will kill you," recalls Schweickart.

This delay caused the crew to be behind schedule, so the EVAs for Schweickart and McDivitt would be restricted to just one daylight pass, and would only include the opening of the hatches of the Command Module (CM) and the LM. This wasn't a disaster, it just meant that the crew were behind a bit and restricted with their valuable time. It was the fourth flight day that saw the two venture outside the confines of the spacecraft and see the vast emptiness of space and all its beauty. The plan was that Schweickart would exit Spider, transfer to the open hatch of the CM and then return - all of which had to be done in the space of just over two hours. Schweickart once again suited up, this time wearing the new extravehicular mobility unit backpack which provided constant communication and oxygen, as well as having water circulate the suit in order to keep his body cool. After the module was depressurised and the hatch was open, the only thing keeping the Lunar Module

The crew

Right:
The Apollo 9 crew, from left to right: Lunar Module pilot Russel 'Rusty' Schweickart, Commander James A McDivitt, and Command Module pilot David R Scott

Above left:
The CSM, Gumdrop, was photographed from the LM, Spider, over New Mexico

© NASA; Rolls Press/Popperfoto/Getty Images

Above: David Scott inside the CSM

Right: Schweickart pictured during his first EVA, floating outside the LM

The aims of Apollo 9

1 Overall check of the launch vehicle and spacecraft systems

2 First flight of the Lunar Module and performing rendezvous and docking procedures with the Command Service Module

3 Test the extravehicular mobility unit backpack for future spacewalks

© NASA;

pilot tethered to the spacecraft for just over an hour was a seven-metre (25-foot) nylon rope.

Schweickart recalls his EVA fondly, saying, "I remember being way up the front of the Lunar Module with my hand on the handrail, and I just let go. With one hand I swung myself around and looked at the Earth; the Command Module was also in that direction, but mainly I could see the Earth, the black sky and the black universe above it. I just said to myself: 'This is my time to be a human, not to be an astronaut. I'm not going to think about what's next on the checklist. My job is to be a sponge, to just let this come in through the spacesuit and into me as a human being.' And that happened."

Scott also completed an EVA in this time, but was reliant on the CMS systems for life support. This spacewalk was also over the space of an hour, and in that time both the Command and Lunar Module pilots took photos of space and retrieved thermal samples from outside the spacecraft.

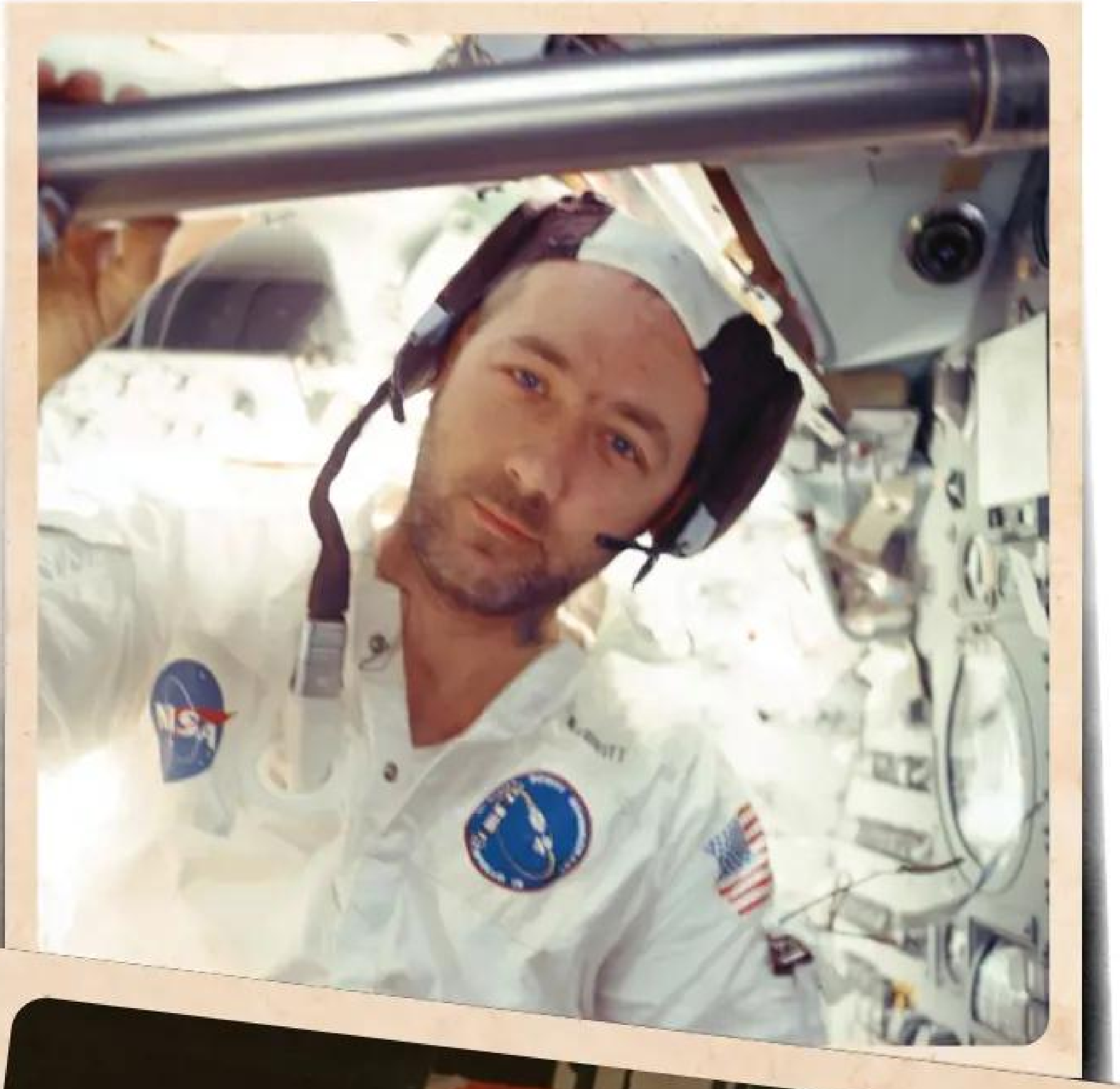
The fifth day held a new test – the crewed undocking and rendezvous of the LM and CSM. In Spider were McDivitt and Schweickart, with Scott remaining in Gumdrop. After months of simulations and training on the ground, the time had come to cut the cord and see if the LM would be capable of lowering humans down to the Moon. When undocking began, something wasn't right. "There were some very small little latches that had to release, and in the simulator on the ground, when we did the procedure everything worked well. When Dave [Scott] pushed the switch and let it go in the actual situation, the probe had not fully extended. He just hit the switch and let it go – which is what we did in the simulator on the ground – but when it reached the end of its travel pushing the Lunar Module away, those little latches, as soon as he let go, went back out, and so we went 'clunk' and stopped," says Schweickart.

"We kind of looked at each other and wondered, 'what was that?'. McDivitt and I said we should probably redock and figure out what happened. We wanted to let the ground team work through it and figure out what happened, and then do it again. At about that time Dave looked up and saw that we weren't separated, and he just hit the switch again. As we started to drift off, we looked at each other and said: 'Well, too late now! So we'll find out when we come back from the rendezvous in eight hours if anything is wrong.'"

After the eight hours the crew had successfully redocked to the CSM, and the experience was deemed a massive success! The final four days of the mission did not include any major tests or experiments that would affect the following Apollo missions. Instead, the Apollo 9 crew conducted Earth resource and multispectral terrain photography experiments over the southern United States, Mexico, Brazil and Africa.

On 13 March 1969, the tenth day of flight that saw them complete 151 revolutions around Earth, the crew made a successful splashdown into the Atlantic Ocean – about 549 kilometres (341 miles) north of Puerto Rico. This concluded what was a massive success for the Apollo program and NASA. "The primary lesson from our experience on Apollo 9 was that everything worked well. We'd had a lot of problems in Gemini doing EVAs with a suit, and they were largely unsuccessful, but we had the brand-new suit. I had to go on the EVA, the first experience of going outside, and fortunately, nothing really dangerous happened. We also had the backpack that was going to allow us to run around on the Moon, so that was a very important test that we did in Apollo 9," concludes Schweickart.

> "I remember being way up the front of the Lunar Module with my hand on the handrail, and I just let go" **Rusty Schweickart**



Left: The Apollo 9 mission was the first to test the Lunar Module

Top right: McDivitt was pictured in the Lunar Module, flaunting his beard growth after a few days in space

Lower right: After their return, the Apollo 9 crew cut a 159-kilogram (350-pound) cake made in their honour

Apollo 10 headed for the Moon with arguably more risk, but did not make the cut for a lunar touchdown

APOLLO 10

The dress rehearsal

Reported by Lee Cavendish

© NASA; SpoonGraphics

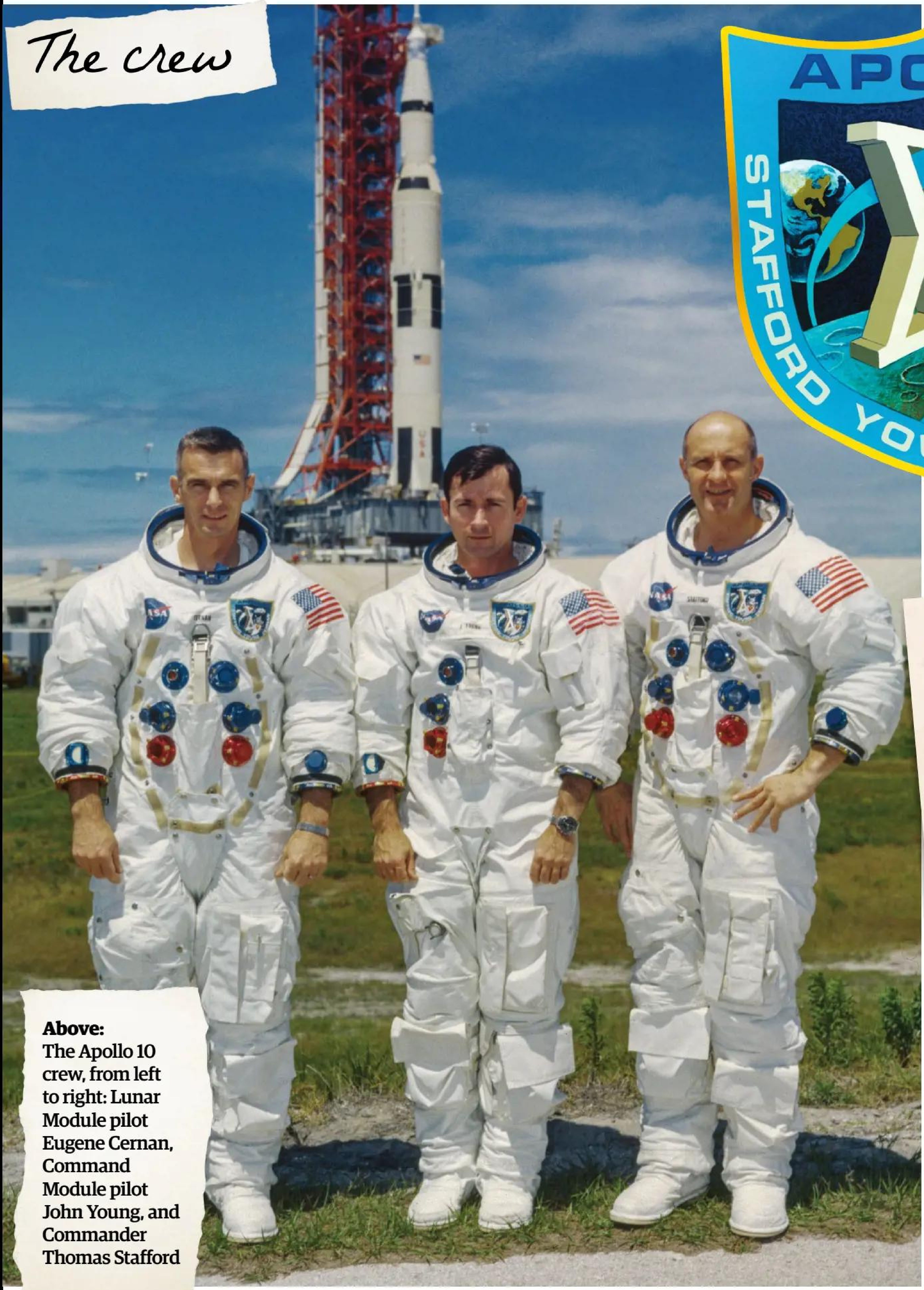
Just a few months after the Apollo 9 mission, on 18 May 1969, was the launch of Apollo 10. This mission saw three of NASA's finest astronauts perform the 'rehearsal' for the Apollo 11 mission – they left Earth, went to the Moon and made a Lunar Module descent, but didn't actually make the historic touchdown. The Apollo 10 mission put everything in place so that Apollo 11 could cement its place in history books.

The trio of cosmic adventurers consisted of commander Thomas Stafford, Lunar Module pilot Eugene Cernan and Command Module pilot John Young. These three were no amateurs in spaceflight: it was Stafford's third, Young's third and Cernan's second spaceflight, and it wouldn't be their last. Stafford went on to be commander of the US-Soviet Apollo-Soyuz Test Project, and Young and Cernan later revisited the Moon as part of the Apollo 16 and 17 missions respectively.

On the afternoon of 18 May, the three NASA astronauts boarded a Saturn V rocket at Launch Complex 39B of the Kennedy Space Center in Florida. At 4:49pm UTC (12:49pm EDT), the Saturn V rocket was launched and the mission had begun – practice for the 'big time'.

After launch the Command Module, nicknamed 'Charlie Brown', and the Lunar Module, 'Snoopy' – famous characters from the comic strip *Peanuts* – all wrapped up in the Command and Service Module

The crew



Above: The Apollo 10 crew, from left to right: Lunar Module pilot Eugene Cernan, Command Module pilot John Young, and Commander Thomas Stafford

Left: Back on Earth NASA employees watched progress from the Mission Operations Control Room in Houston, Texas

Left below: The Lunar Module was nicknamed 'Snoopy' after the *Peanuts* character; he became the mission's mascot

(CSM), orbited the Earth one-and-a-half times before its trans-lunar injection. This put the CSM on course towards the Moon, a journey that hadn't been made since the Apollo 8 mission. It then detached from the third stage of the Saturn V rocket.

So far so good. The astronauts now had to wait as they journeyed 384,400 kilometres (238,900 miles) over the course of approximately three days to reach the Moon. There were tasks to do in the meantime; astronauts in space for that amount of time can't just sit around and do nothing! One thing that kept them busy was providing the first live colour-television transmissions from space. The first of these occurred only a few hours after launch, as they broadcasted the docking between Snoopy and Charlie Brown. "I had flown two flights before, and space is so beautiful. You look down at the Earth, and all we had was Hasselblad film and a little 16-millimetre [0.6-inch] camera. It was just short clips, so we said, 'We ought to be able to do better then this,'" said Thomas Stafford in an interview with *Spaceflight Insider*. "We put the colour TV on Apollo 10 about a week before we launched, and we had more prime colour TV time than there was on Apollo 11." Throughout the mission 19 colour television transmissions were made, totalling almost six hours of stunning visuals that people on Earth had the pleasure of seeing in real-time.

On 21 May 1969 the Apollo 10 crew had finally reached their destination and entered into an orbit around the Moon, flying approximately 110 kilometres (69 miles) over its surface. This returned the first colour-television images of the Moon's surface to Earth. After orbital insertion around the Moon it was finally time to test the most important aspect of the mission: the lunar descent. This operation is what would take humans down to the Moon's surface – though they wouldn't land yet.

Stafford and Cernan took their places in the Lunar Module ready for descent, but what was stopping these two men from becoming the

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The aims of Apollo 10

1 To demonstrate all support facilities are up to standard for a lunar mission

2 Evaluate the Lunar Module's performance during a descent

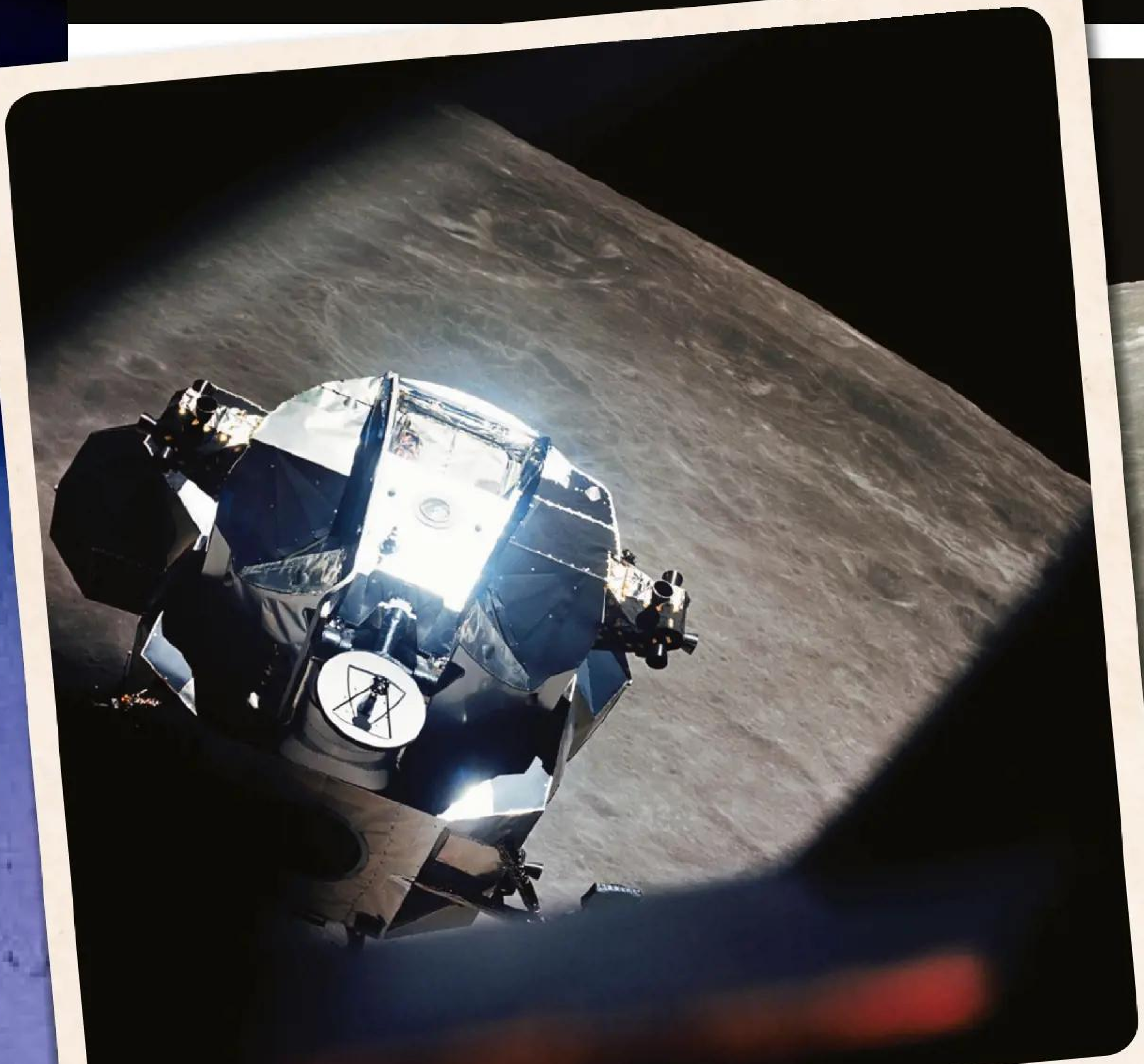
3 Perform lunar landmark tracking, particularly the Sea of Tranquillity

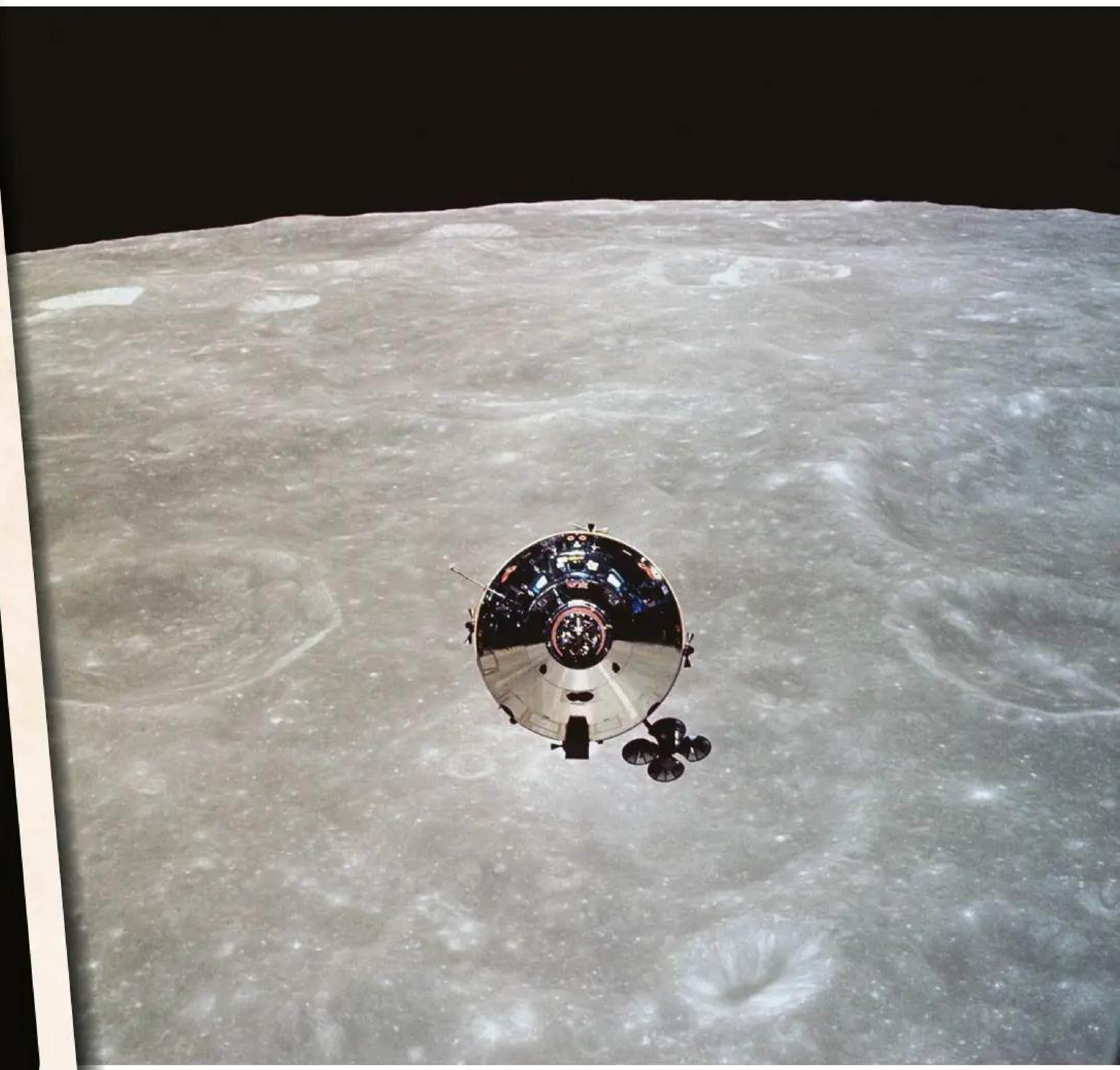
Left:
Only Apollo 8 had witnessed Earth in all its glory before Apollo 10

Bottom left:
The Lunar Module, Snoopy, rendezvoused with the Command Module, Charlie Brown, after its close encounter with the Moon

Bottom right:
Charlie Brown photographed from Snoopy soon after separation

> "When you go to the Moon and you watch the Earth, you see something very strange in it, something very familiar" **Eugene Cernan**





ones in the history books and making the first touchdown on the lunar surface? At this point the Lunar Module was too heavy for a touchdown, and the crew needed additional training if they were to perform one. For two out of the three Apollo 10 astronauts, their time would come eventually.

A peculiar noise was soon heard by the astronauts as Stafford and Cernan separated from Young on the farside of the Moon. In the transcripts and recordings, finally released in 2008, the high-pitched sound becomes apparent and brings on an exchange between the astronauts trying to understand what it could be. It begins with Cernan saying: "That music even sounds outer-spacy, doesn't it? You hear that? That whistling sound?" This occurred on their fifth day in space, and it's obvious that this wasn't something they'd heard before. Michael Collins also noted a whistling sound while on the Apollo 11 mission. After some investigation it was discovered to be interference between the VHF radios on the two different spacecraft.

Continuing with their mission, the priority was testing the lunar descent procedure that would take Neil Armstrong and Buzz Aldrin to the Sea of Tranquillity. The descent was successful, taking Stafford and Cernan just 14.5 kilometres (nine miles) above the surface; then the closest any human had gotten to another celestial body. The Moon was tantalisingly close, and everything was seemingly running well with no major complications. But this changed as they ejected the Lunar Module's ascent pod from the descent stage. "I had all the switches set instinctively, as we will do. Tom reached over and changed positions with the guidance switch, because he knew it had to be changed to X, but I had already changed it to X," recalled Cernan on a Discovery Channel series called *Rocket Science*. "And so when it fired it was on a primary guidance system [as opposed to the abort guidance system], and a primary guidance system didn't know where to tell it to go, so we did separate, and spun out of control.

"I remember seeing a lunar horizon go by in different directions about 18 times in some 15 seconds. Tom took it back from the computer, got it under control; we gave it back to the abort guidance system. We got the burn on time and rendezvoused and everything turned out all right." This was a close call. What Stafford and Cernan didn't know at the time was that Snoopy was two seconds away from crashing into the surface of the Moon. The mission could have ended in disaster, and who knows what ramifications that would have had for the Apollo 11 mission. The fact that this was all broadcast live also meant that the public could have just witnessed a terrible event, but the astronauts regained control. Luckily the only bad result was Stafford yelling some rather understandable profanity on an open channel to the world!

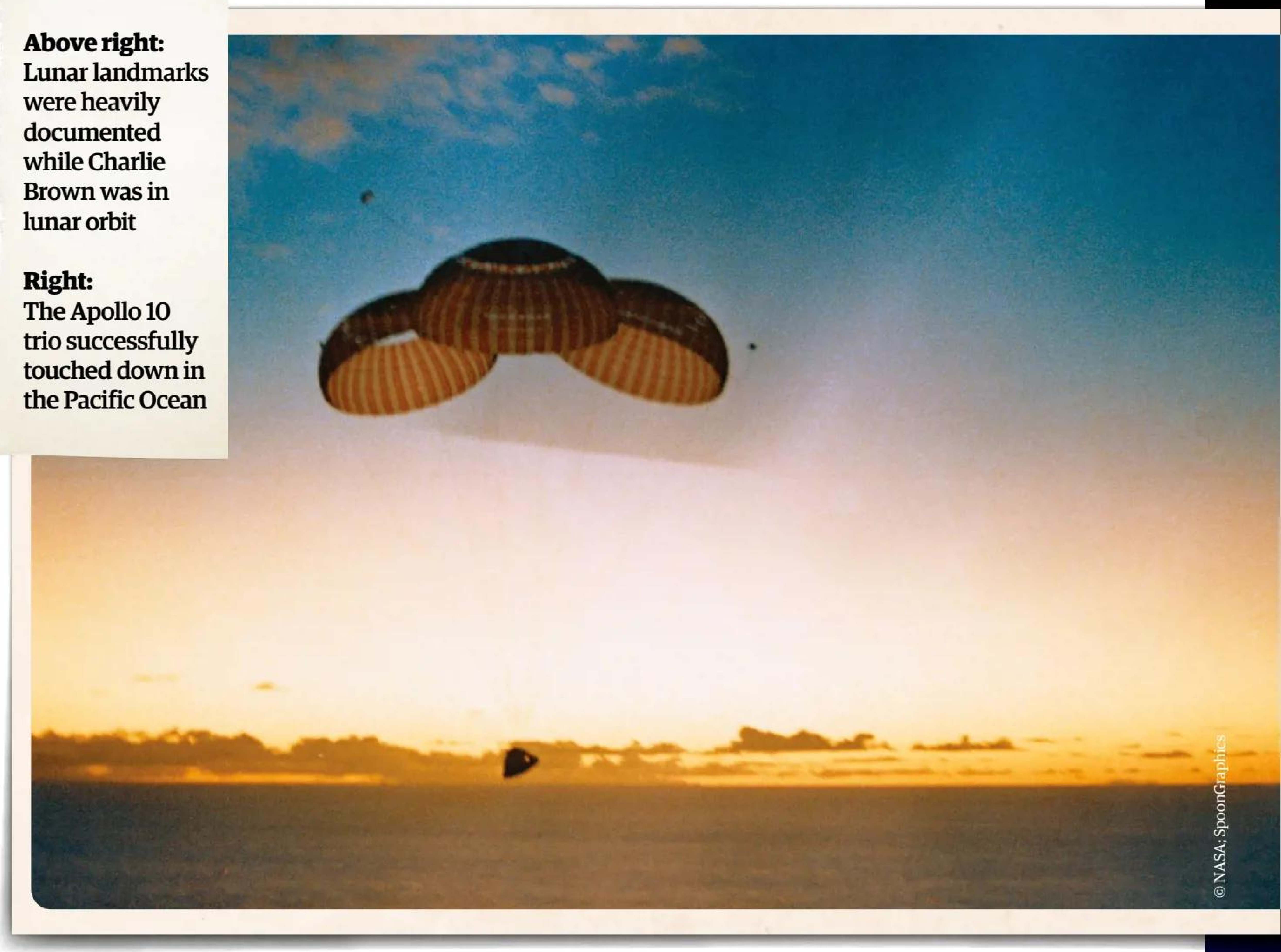
All in all the mission was successful, and that story did not come to light until at least 40 years later. To unknowing ears the mission was smooth from start to finish, and no one knew for a long time that Cernan and Stafford came within two seconds of crashing into the lunar surface. However, there were aspects that were tested that would prove vital for the Apollo 11 mission, as Cernan explained: "We also checked out the landing radar on that mission and found out it had been programmed improperly. Had that happened on Apollo 11 they would not have landed. So we found out some interesting things on Apollo 10."

With half the mission done, the next objective was to make it back to Earth and land safely, which meant plucking Stafford and Cernan out from their ascent and back into Charlie Brown. On the 16th orbit of the Moon, Young rendezvoused with Snoopy, and their next 15 orbits were spent lunar landmark tracking and putting their Hasselblad cameras to good use. Afterwards Apollo 10 entered its trans-Earth trajectory, starting the trio on their three-day journey back home.

Apollo 10 would make it back to Earth and safely re-enter its atmosphere on 26 May 1969. This was the final hurdle, and 15 minutes before re-entry Charlie Brown was separated from the rest of the Service Module to begin its descent. During re-entry astronauts have to deal with terrifying speeds as they plummet down to the sea. Apollo 10 was even scarier – it actually holds the record for the top speed achieved by a manned spacecraft, going 39,897 kilometres (24,791 miles) per hour. This was much to Stafford's delight, as he previously stated in the same interview: "I always loved to fly. I wanted to be a fighter pilot and I wanted to fly the latest things to go higher and faster. I finally did go faster with Apollo 10."

Charlie Brown splashed down in the Pacific Ocean at 4:52pm UTC (12:52pm EDT) and was retrieved by a United States Navy ship, the USS Princeton. This concluded what would turn out to be a successful, important and frankly underrated mission in terms of the whole success of the Apollo program. But there is a philosophical side of going to the Moon; it is not just to test technologies and satisfy humankind's need to explore as many frontiers as possible.

Space travel can be an extremely moving experience for the individual. Cernan explained this extremely poetically: "When you go to the Moon and you watch the Earth evolve in front of you, you see something very strange in it, something very familiar. You're not flying around the Earth anymore. You're not flying through sunrises and sunsets. Without even rolling your eyeballs, you're looking across oceans and continents. You're watching as the Sun rises on one side of the world and sets on the other side all in the same instance. You're looking at a blackness beyond your perception that envelops the Earth. The infinity of time, the infinity of space, the endlessness of it all. I'm not sure what it is, but I'm sure it exists because I saw it with my own eyes."



Above right: Lunar landmarks were heavily documented while Charlie Brown was in lunar orbit

Right: The Apollo 10 trio successfully touched down in the Pacific Ocean

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Giant Leaps

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APOLLO 11

One giant leap for mankind

What really happened the day we landed on the Moon?

Reported by Nick Howes

It's hard for many to comprehend that just over 50 years ago, humankind achieved one of the greatest technical feats of all time. Less than nine years after President Kennedy had set the goal of landing a man on the surface of the Moon and returning him safely to Earth, NASA achieved that most astonishing aim on 20 July 1969.

Those intervening years had been a white-knuckle ride. Beginning with Alan Shepard's 15 minute sub-orbital Mercury flight in 1961, NASA progressed through a series of milestones in their mission to reach the Moon. There was the loss of a Mercury capsule and the near-drowning of its pilot Gus Grissom; John Glenn's re-entry with a retro-rocket still attached to his Friendship 7 capsule; a slew of hugely successful Gemini missions including one that almost span out of control, potentially threatening the life of the astronaut who in 1969 would take that first historic step; and then four fully flown Apollo missions, two in low Earth orbit, two that orbited the Moon and only one to test the full system. NASA had to endure the catastrophic loss of Grissom and his two crew mates, Edward White and Roger Chaffee in 1967 in Apollo 1's tragic fire on the launch pad, but the space agency had resolved to carry on, completely redesigning the Command Module and carrying out major changes to the Lunar Module in that short space of time.

Amid triumph and tragedy, on 16 July 1969 NASA was ready to go to the Moon. Yet the trials and tribulations of the previous years were not over and the three-man crew of Apollo 11 – Neil Armstrong, Buzz Aldrin and Michael Collins – were facing one of the most dramatic spaceflights in history.

We recall the historic first words said on the lunar surface, and the elation of the largest TV audience in history at that time when they saw those grainy black and white images from the Moon, but there is so much more to the story of Apollo 11 that may not be as well known.

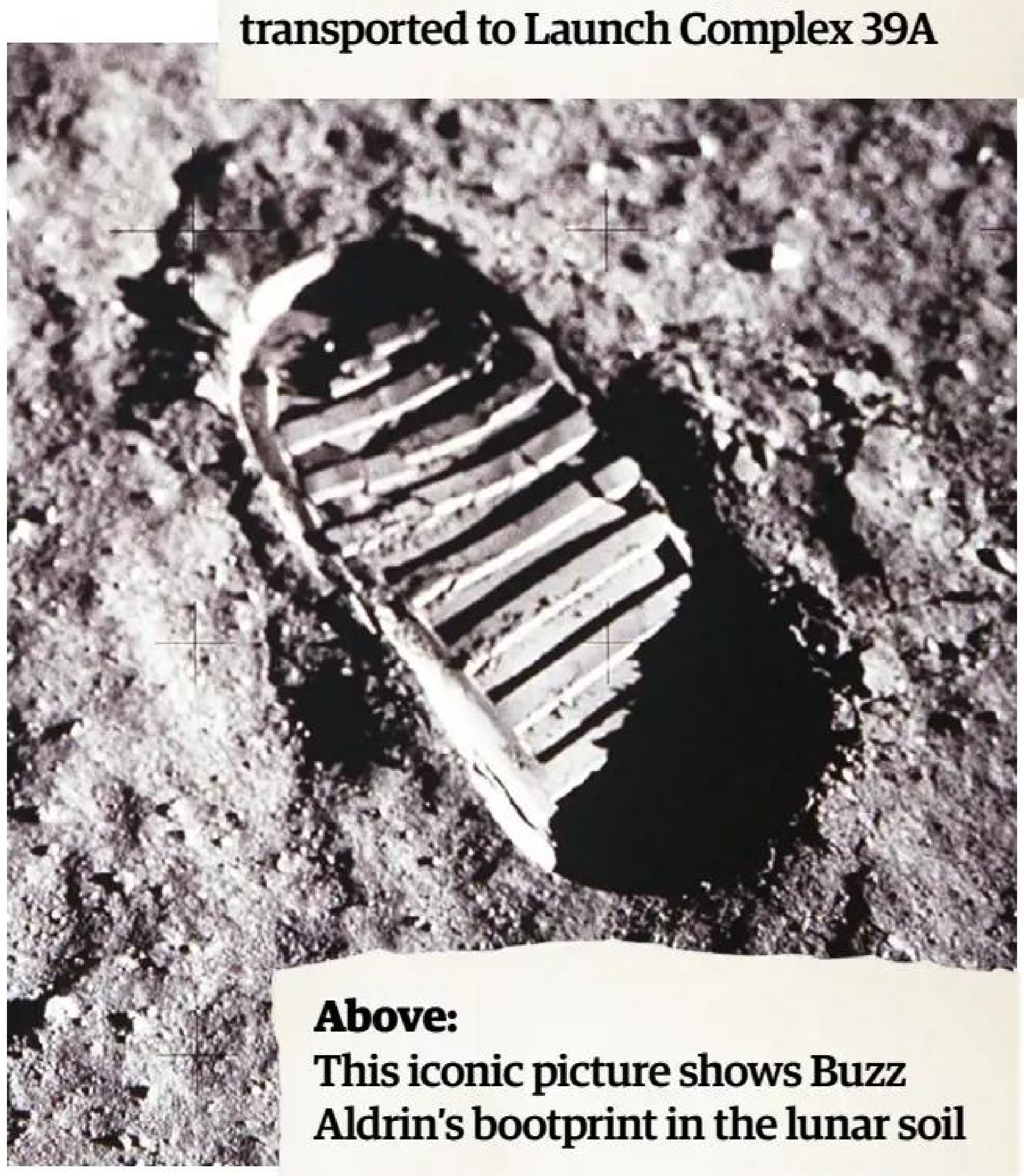
Their first task, of course, was to leave Earth on top of the mighty Saturn V rocket – the tallest, most powerful rocket ever built. Many astronauts who were propelled into space by the Saturn V describe it as being a very smooth ride. Neil Armstrong is quoted as saying that while the launch for all those watching on Cocoa Beach or at Cape Canaveral was deafening, the crew could detect a slight increase in background noise, a lot of shaking, and feeling akin to being onboard a large jet aeroplane on take-off. Yet as smooth a ride as it was, being on top of that much rocket fuel was always going to be a dangerous experience.

"A space mission will never be routine because you're putting three humans on top of an enormous amount of high explosive," Gene Kranz, flight director for Apollo 11's lunar landing, told **All About Space** in an interview.

If there were any nerves, the astronauts certainly didn't seem to be feeling them, according to Buzz Aldrin. "We felt that our survival was in the probability of 99 per cent. There were a lot of risks

"A space mission will never be routine… you're putting three humans on top of an enormous amount of high explosive" **Gene Kranz**

Above:
Armstrong waves to well-wishers in the Manned Spacecraft Operations Building as he, Collins and Aldrin prepare to be transported to Launch Complex 39A



Above:
This iconic picture shows Buzz Aldrin's bootprint in the lunar soil

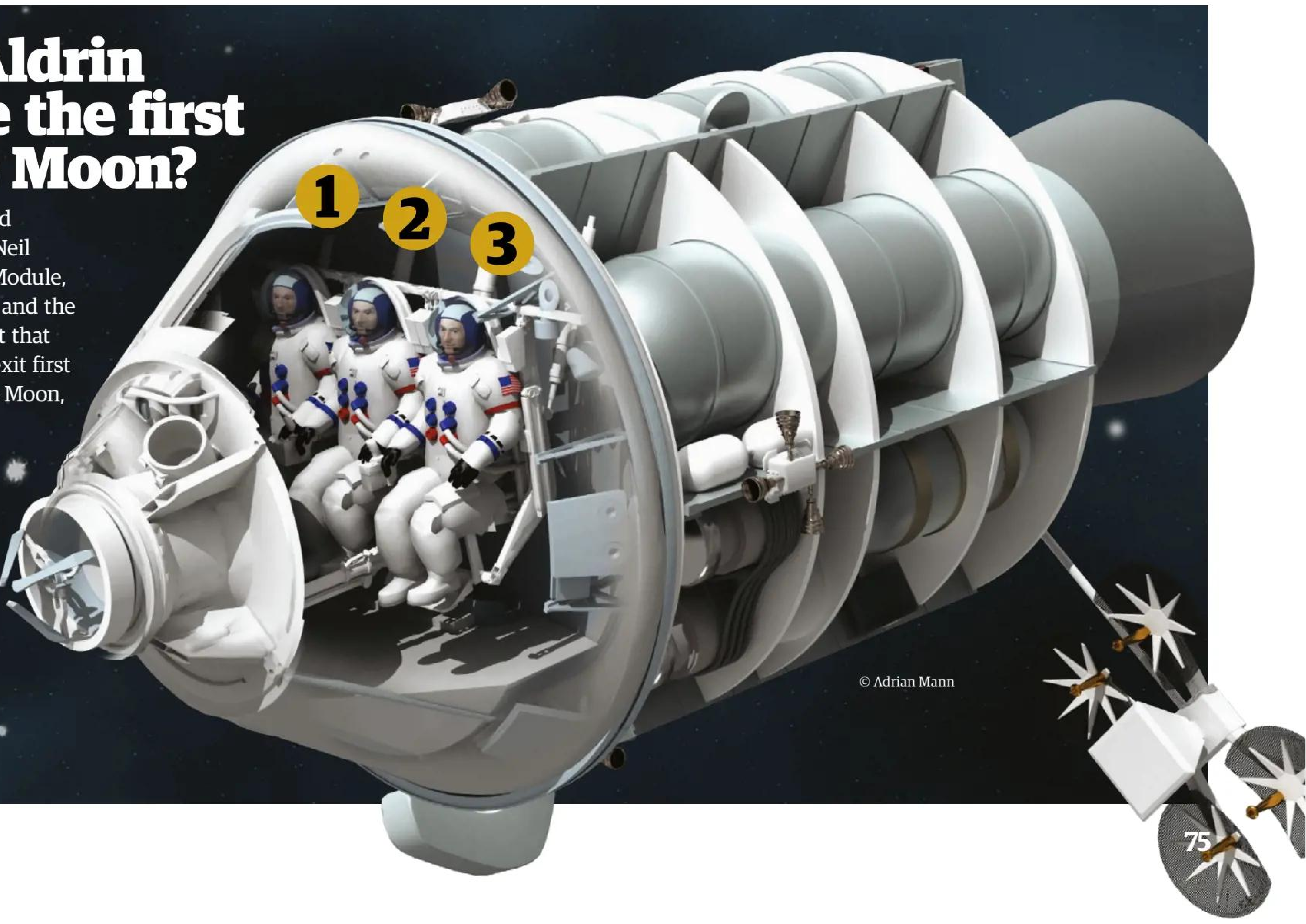
Was Buzz Aldrin meant to be the first man on the Moon?

The seating plan in the Command Module. When Buzz Aldrin and Neil Armstrong moved to the Lunar Module, it's thought that the seating plan and the position of the entry hatch meant that Armstrong was better placed to exit first and become the first man on the Moon, rather than Aldrin.

1 Michael Collins (Command Module pilot)

2 Buzz Aldrin (Lunar Module pilot)

3 Neil Armstrong (Commander)



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BUZZ ALDRIN

“Somebody said that [me not taking pictures of Neil] was intentional”

After returning to Earth, hardly any shots of the first man on the Moon led Buzz Aldrin to be questioned

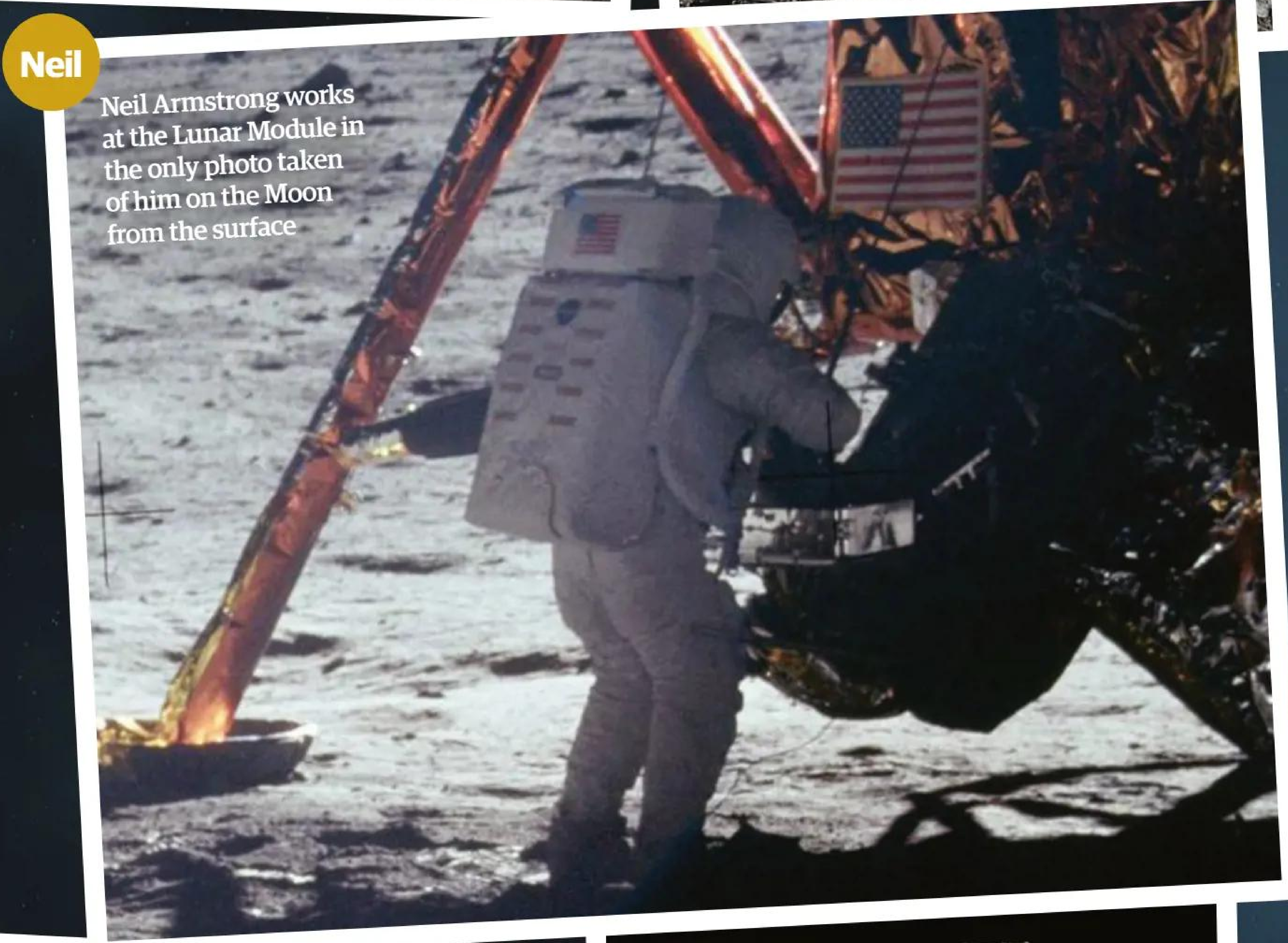
It’s said that Aldrin was getting Armstrong back by taking no photos of him on the Moon in retribution for the latter getting the honour of being the first to set foot on the Moon. However, and according to Aldrin, he was about to take a picture of Armstrong at the flag ceremony when President Nixon called, distracting them from the task. “As the sequence of lunar operations evolved, Neil had the camera most of the time, and the majority of the pictures taken on the Moon that include an astronaut are of me,” Aldrin states. “It wasn’t until we were back on Earth and in the Lunar Receiving Laboratory looking over the pictures that we realised there were few pictures of Neil. My fault perhaps, but we had never simulated this during our training.”

Before his death in 2012, Armstrong defended Aldrin, stating: “We didn’t spend any time worrying about who took what pictures. It didn’t occur to me that it made any difference, as long as they were good… I don’t think Buzz had any reason to take my picture, and it never occurred to me that he should.”

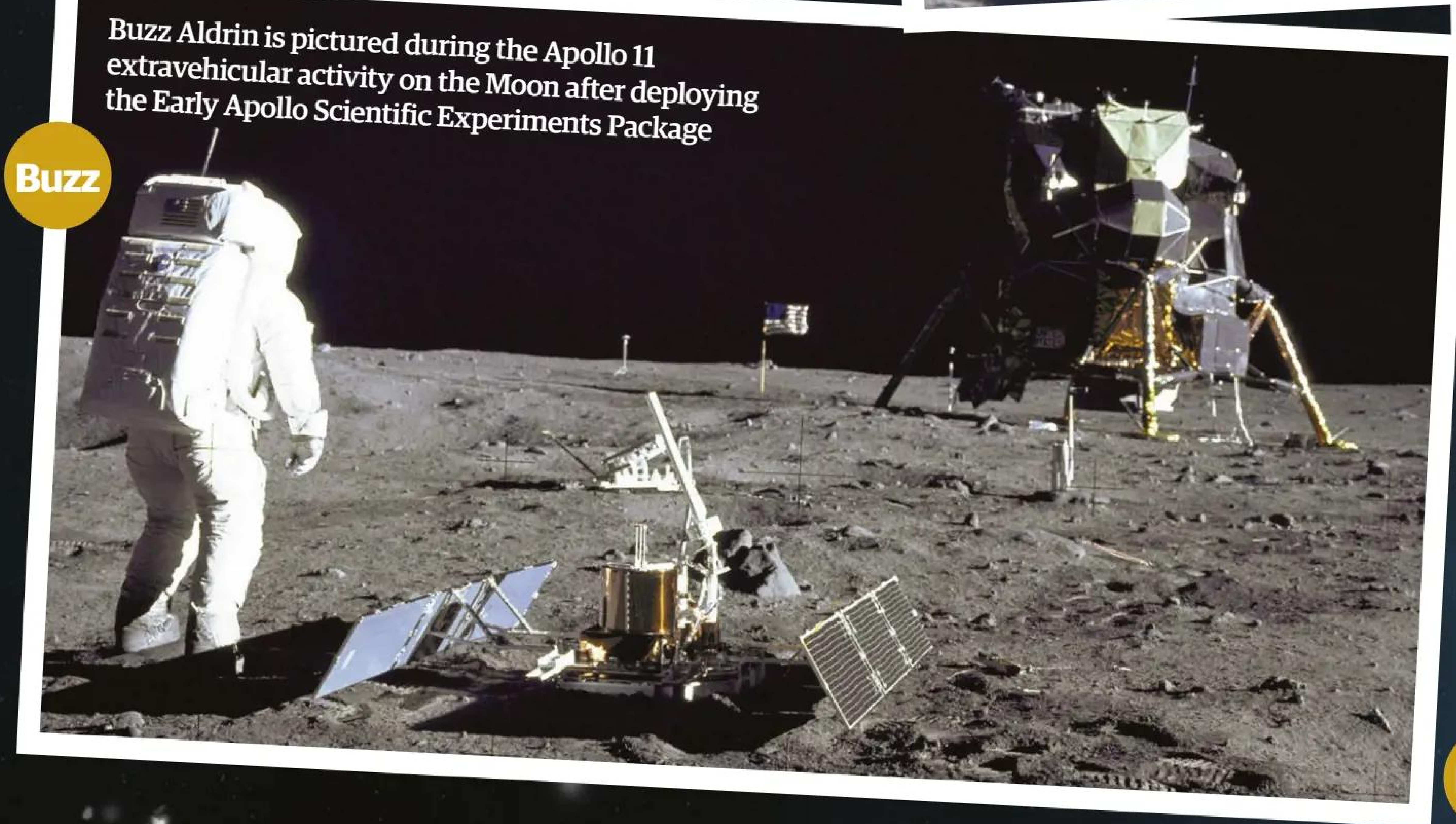
“When I got back and someone said, ‘There’s not any of Neil,’ I thought, ‘What in the hell can I do now?’ I felt so bad about that,” says Aldrin. “And then to have somebody say that might have been intentional… How do you come up with a nonconfrontational argument against that?”

Buzz Aldrin moves toward a position to deploy two components of the Early Apollo Scientific Experiments Package (EASEP) on the surface of the Moon during the Apollo 11 extravehicular activity

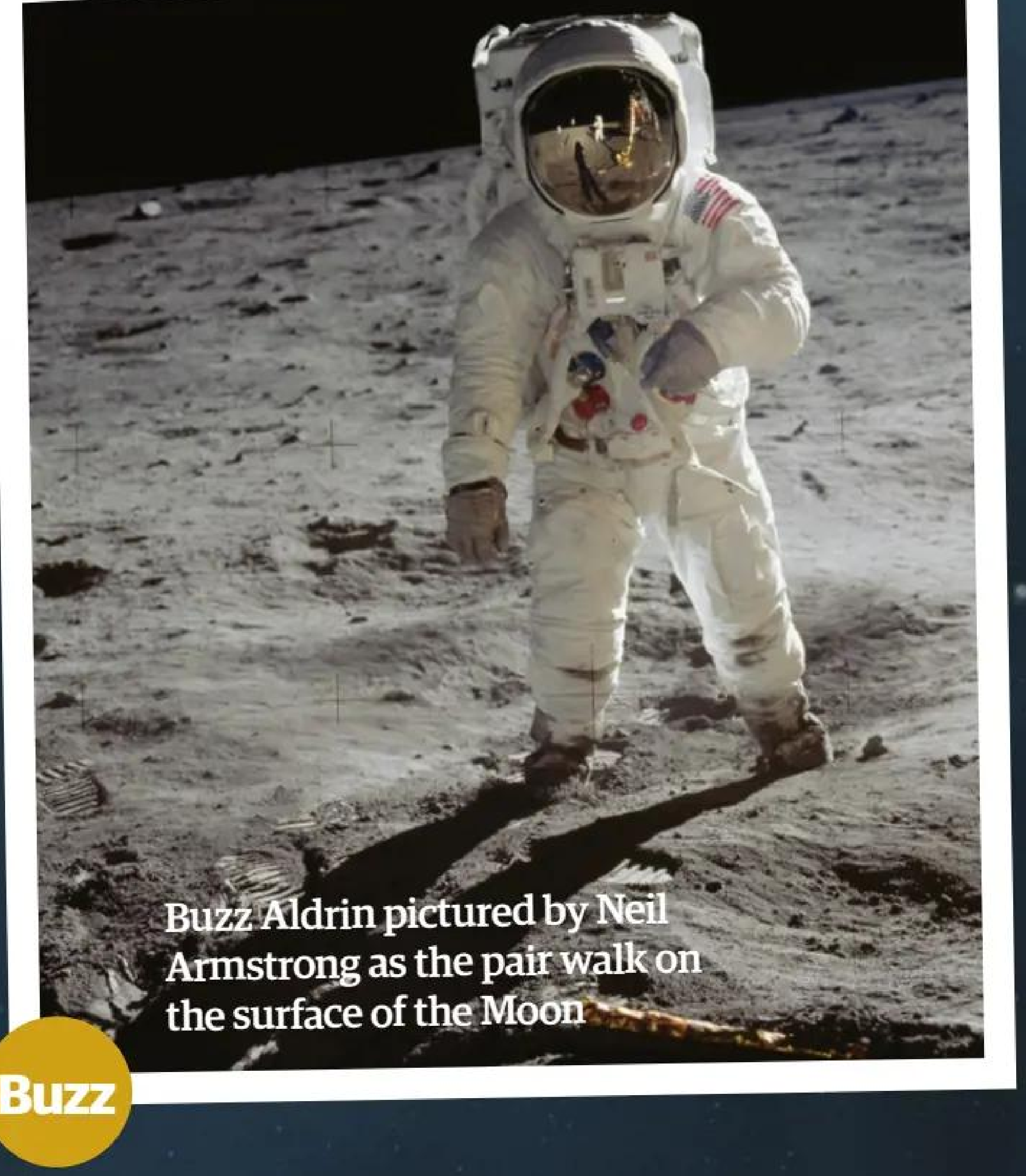
Aldrin salutes the deployed United States flag on the lunar surface



Neil Armstrong works at the Lunar Module in the only photo taken of him on the Moon from the surface



Buzz Aldrin is pictured during the Apollo 11 extravehicular activity on the Moon after deploying the Early Apollo Scientific Experiments Package



Buzz Aldrin pictured by Neil Armstrong as the pair walk on the surface of the Moon involved but there were a lot of points to abort the mission short of continuing on something risky."

Once in space, the Command and Service Module had to rotate and dock with the Lunar Module, which was embedded in the final S-IVB stage of the Saturn V rocket. After the two spacecraft had mated, onwards they flew to the Moon, leaving the S-IVB stage trailing in space behind them.

Some time later, the crew spotted something strange outside. A light that appeared to be following them. When Michael Collins used the onboard telescope to view it, he couldn't make it out – it looked like a series of ellipses but, when focusing the telescope, it seemed L-shaped, but that could have just been the way sunlight was glinting off it.

Reticent to tell mission control in Houston, Texas, that they were being raced to the Moon by a UFO, the crew cautiously asked where the S-IVB rocket stage was. "A few moments later they came back to us and said it was around 6,000 miles away," recalled Aldrin. "We really didn't think we were looking at something that far away, so we decided to go to sleep and not talk about it any more."

Aldrin doesn't believe it was an alien spaceship, but that it was more likely the Sun reflecting off one of four metal panels that fell away from the rocket stage when they docked with the Lunar Module.

For almost four days Apollo 11 flew towards the Moon, where Armstrong and Aldrin climbed into the Lunar Module – the Eagle – and said goodbye to Collins, who was to remain in the Command Module in orbit around the Moon.

As the Eagle flew around the far side of the Moon, things in mission control were growing tense. "There was a degree of seriousness in mission control that I hadn't even seen in training," said Kranz. "That was when you realised this was the real deal: today, we land on the Moon."

Almost immediately after separating from the Command Module there were problems. Radio communication with the Eagle was sketchy at best and they were coming up to the point of no return, where the landing could no longer be aborted if something was wrong.

"It was up to me to decide if we had enough information to make the go/no-go [decision] and continue the descent to the Moon," said Kranz. So, five minutes before the powered descent to the lunar surface was due to begin, with radio communication cutting in and out, Kranz asked his flight controllers to give him their go or no-go based on the last frame of data that they saw. They all said "go." And after that, things turned from bad to nearly catastrophic.

The spacecraft's guidance computer, developed at MIT under the auspices of Charles Draper (the lab at MIT now bears his name) was a 2MHz system that

"There was a degree of seriousness in mission control that I hadn't even seen in training" **Gene Kranz**

Task Accomplished.....
July, 1969
APOLLO 11
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Below: The flight controllers erupt into applause as Apollo 11 splashes down in the Pacific Ocean on 24 July 1969, successfully completing the mission

Abbreviations
- CSM = Command and Service Module
- CM = Command Module
- SM = Service Module
- LM = Lunar Module

Apollo 11 crew
- Neil Armstrong, Commander
- Buzz Aldrin, Lunar Module pilot
- Michael Collins, Command Module pilot

Mission Control crew
- Bruce McCandless, CAPCOM
- Charlie Duke, CAPCOM

APOLLO 11

The mission as it happened

1

"Roger. Clock."
Armstrong

2

"Roger. Roll."
McCandless

3

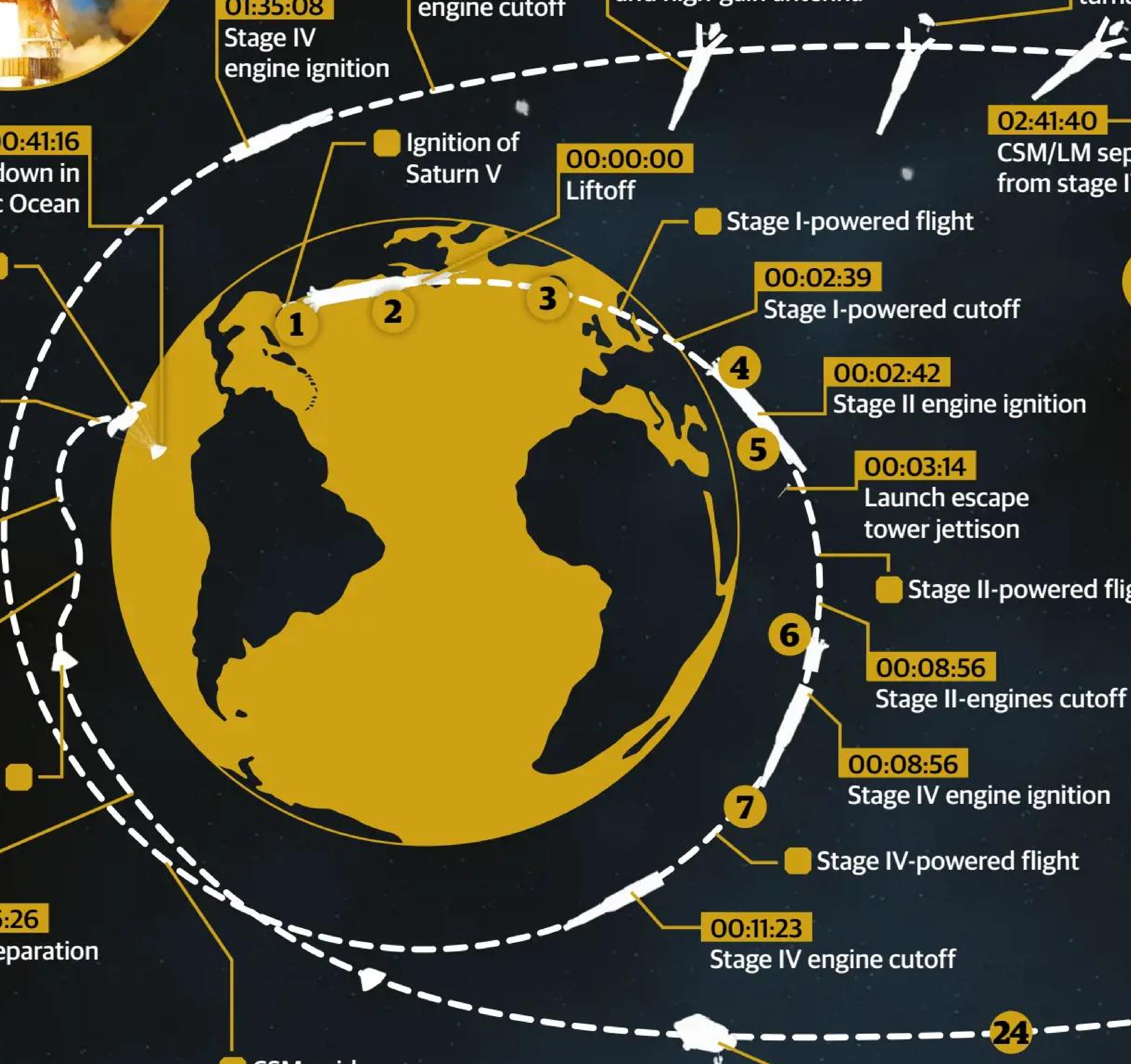
"Roger. 1 50."
Armstrong

"Roger. We copy. We'll be configured and waiting for whatever you want to send down."
McCandless

4

5

"Apollo 11, Apollo 11, this is Houston broadcasting in the blind. Request OMNI Bravo."
McCandless



Ignition of Saturn V

00:00:00
Liftoff

Stage I-powered flight

00:02:39
Stage I-powered cutoff

00:02:42
Stage II engine ignition

00:03:14
Launch escape tower jettison

Stage II-powered flight

00:08:56
Stage II-engines cutoff

00:08:56
Stage IV engine ignition

Stage IV-powered flight

00:11:23
Stage IV engine cutoff

01:35:08
Stage IV engine ignition

01:40:50
Stage IV engine cutoff

01:57:05
CSM guidance system separation and LM adapter, deployment of adapter panels and high-gain antenna

01:58:42
CSM guidance system 180-degree turnaround

02:41:40
CSM/LM separation from stage IV

Navigation sightings

04:43:56
SM ignition

04:44:04
SM engine cutoff

46 hours
Systems status checks
Eat and sleep periods
Data transmit periods

1:52:11:45
SM engine cutoff

199:23:26
SM engine ignition

CSM guidance system reference alignment

200:16:26
CSM separation

Communication blackout period

200,000ft altitude

250,000ft altitude

Heat shield and chute deployed at 24,000ft

Deploy main chute at 10,000ft

200:41:16
Touchdown in the Pacific Ocean

6

"Roger. Oxygen heaters to AUTO, or you can watch them in the ON position, and oxygen fans manual ON."
McCandless

7

"This is Houston. Readback correct. Out."
McCandless

24

"The Earth is really getting bigger up here and, of course, we see a crescent."
Collins

23

"Roger"
Duke

22

All right. The doors are open, and it looks like they are going to stay up without any problem.
Aldrin

21

*"Okay. You can make a Mark, Houston. *** deployed."*
Armstrong

20

"This is too big an angle, Neil."
Aldrin

"Okay."
Collins

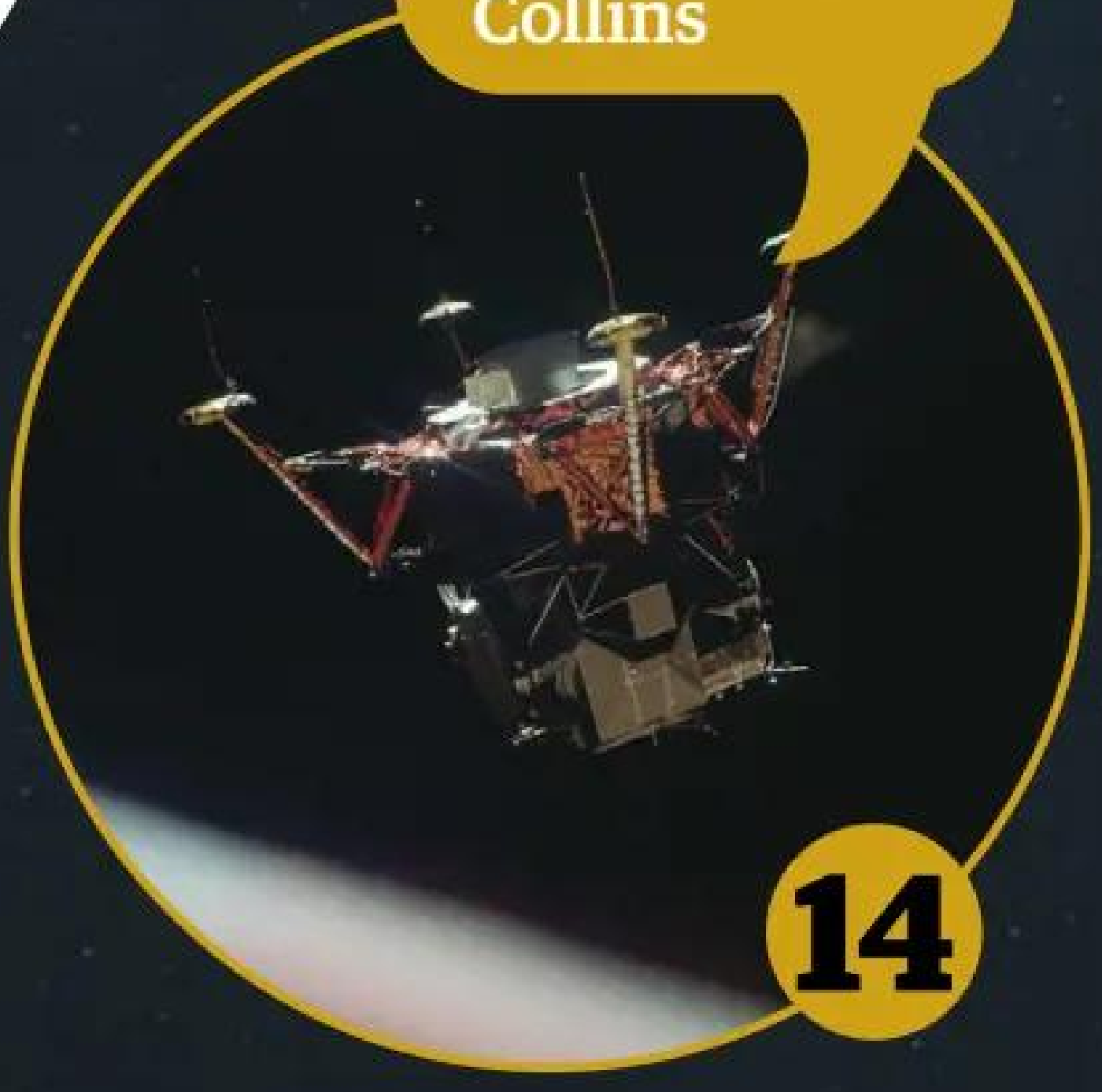
"Apollo 11, Houston. Thirty seconds to loss of signal. Both spacecraft looking good going over the hill. Out."
Duke

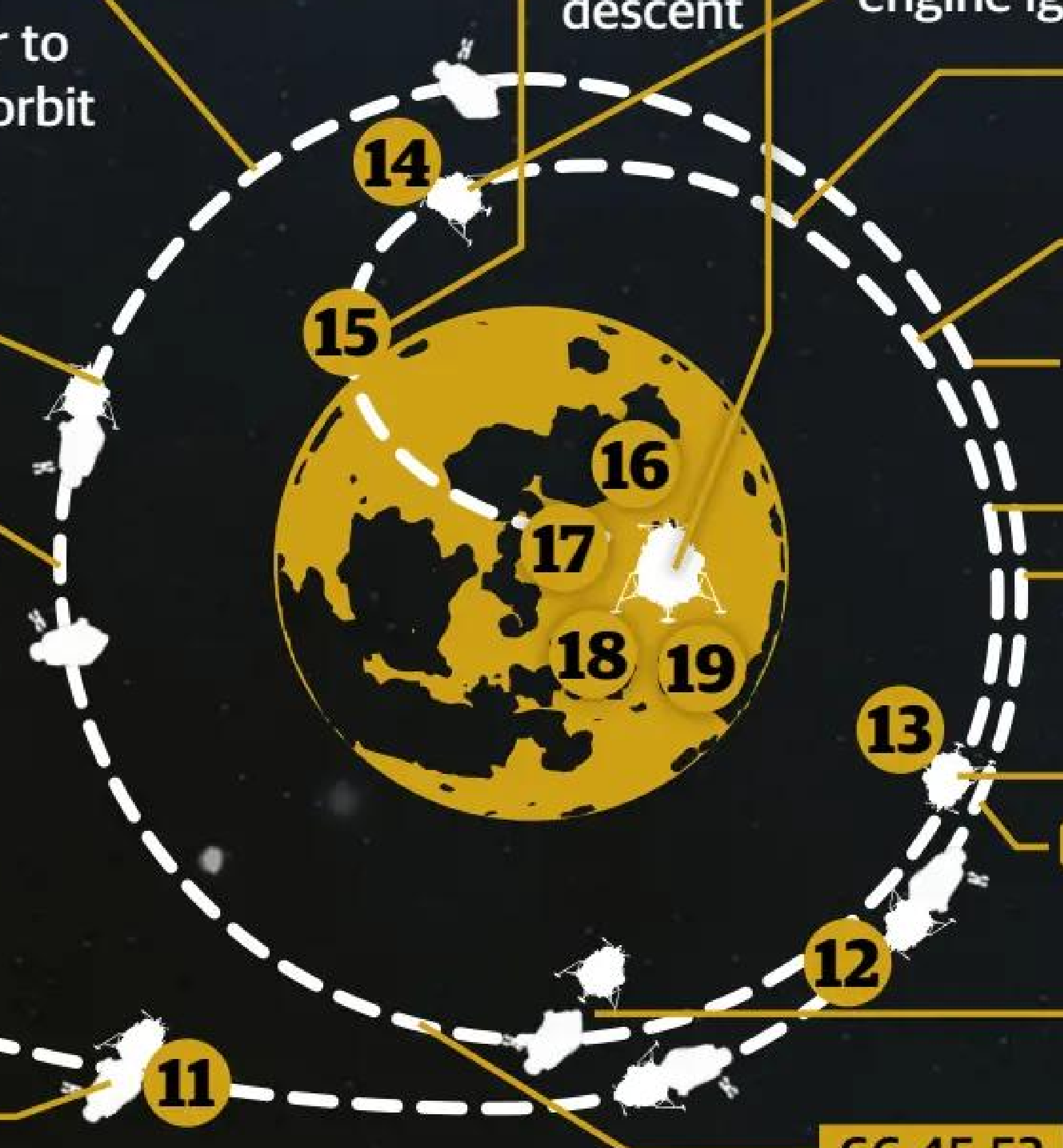
"I think you've got a fine looking flying machine there, Eagle, despite the fact you're upside down."
Collins

"That's a good, reasonable way of describing it. It appears as though it made a difference just sitting back in the tunnel and gazing at all windows; it makes a difference which one you're looking out of. The camera right now is looking out the number 5 window, and it definitely gives a rosier or tanner tinge."
Aldrin

"Okay, no complaints. I was just curious as to what had happened."
Collins

"Apollo 11 is getting its first view of the landing approach. This time we are going over the Taruntius crater, and the pictures and maps brought back by Apollo 8 and 10 have given us a very good preview of what to look at here. It looks very much like the pictures, but like the difference between watching a real football game and watching it on TV. There's no substitute for actually being here."
Armstrong





46 hours
Systems status checks
Eat and sleep periods
Data transmit periods

51:40:59
SM engine cutoff

51:40:51
SM ignition

9 hours
Systems status checks
Eat and sleep period
Data transmit period

Begin LM systems activation and checkout

66:17:43
Pilot transfer to LM, second orbit

64:04:38
Begin navigation sightings

Lunar descent

70:37:45
Lunar touchdown

70:27:17
Lunar descent engine ignition

LM guidance system and reference alignment

69:29:03
LM descent engine cutoff

Begin lunar orbit evaluation

Transfer orbit insertion

63:23:27
Service engine cutoff

69:28:31
LM descent engine ignition

Lunar orbit insertion

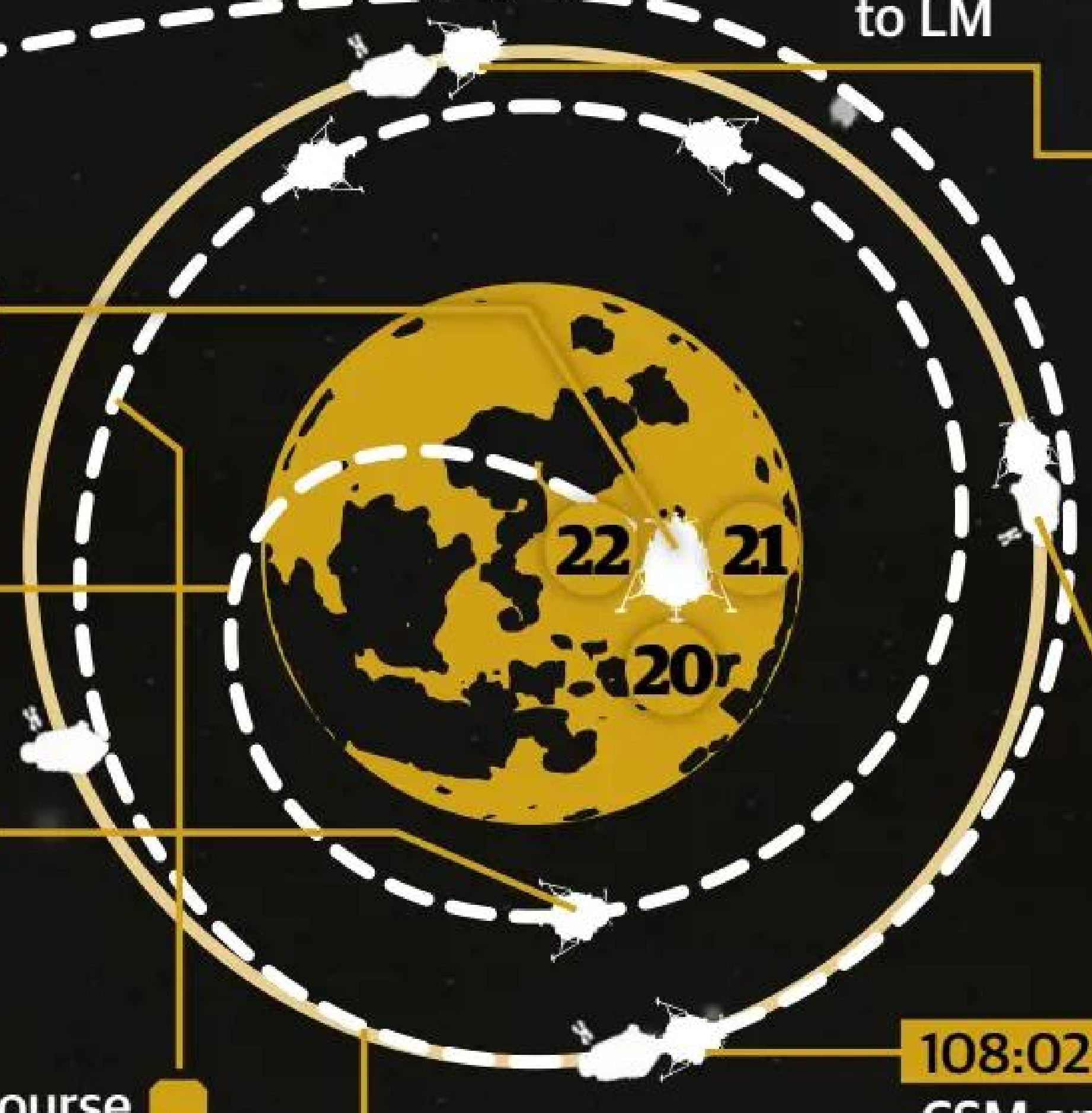
69:05:32
CSM and LM separate on third orbit

62:16:57
SM engine ignition

62:17:01
SM cutoff

66:45:53
Commander transfer to LM

"11, Houston. If that's not the Earth, we're in trouble."
Duke



9 hours
Systems status checks
Eat and sleep period
Data transmit period

109:00:04
CSM and LM separate and LM jettisons

105:19:04
Liftoff

LM ascent

122:11:44
SM engine ignition

Transfer crew and equipment from LM to CSM

28 hours
Systems status checks
Eat and sleep periods

LM ignition

1:52:11:44
SM engine ignition

Midcourse corrections

Rendezvous manoeuvres

108:02:14
CSM and LM initial docking

"See you later."
Armstrong

"Contingency sample is in the pocket. My oxygen is 81 percent. I have no flags, and I'm in minimum flow."
Armstrong

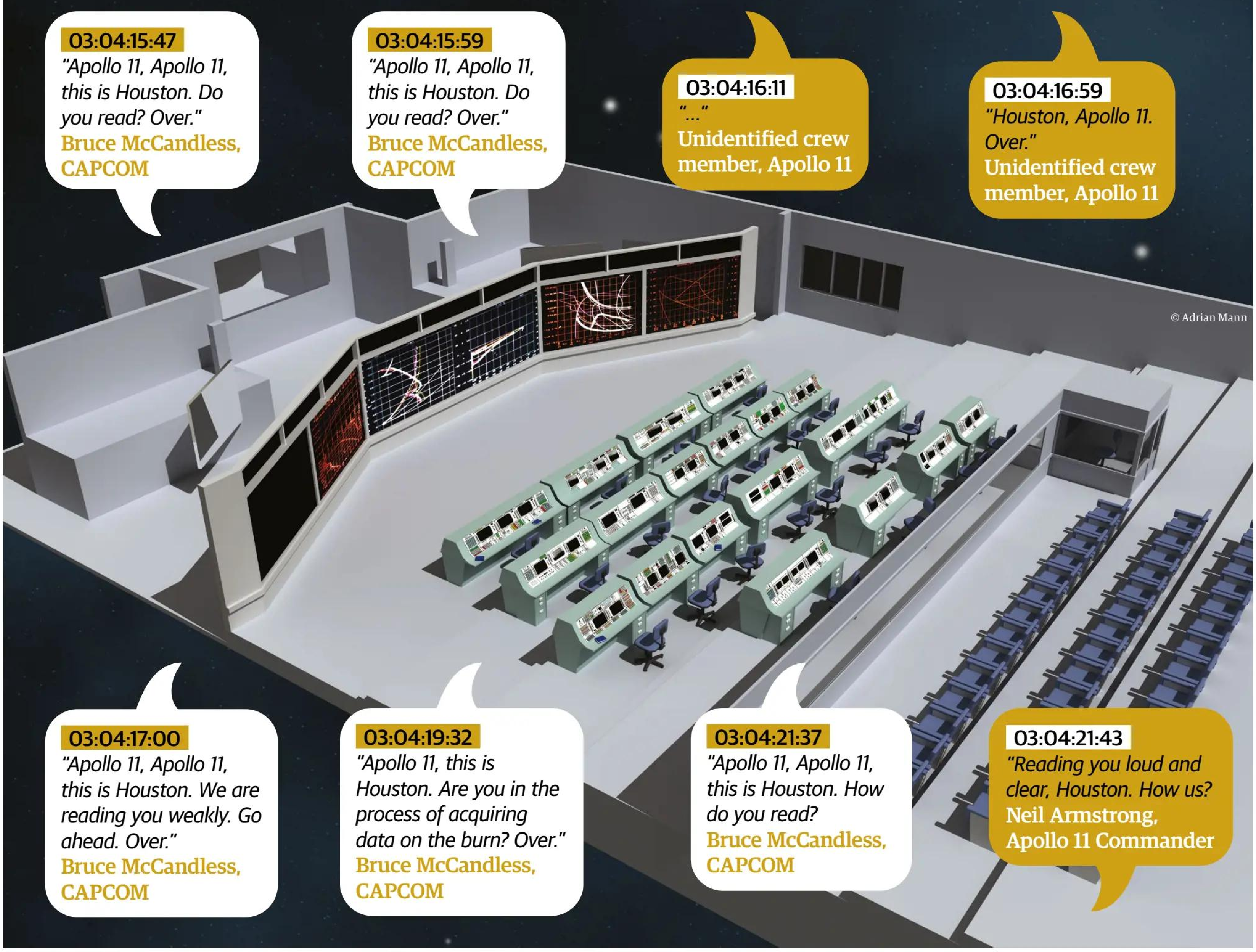
"For those who haven't read the plaque... First there's two hemispheres, one showing each of the two hemispheres of the Earth. Underneath it says "Here Man from the planet Earth first set foot upon the Moon, July 1969 A.D. We came in peace for all mankind." It has the crew members' signatures and the signature of the President of the United States."
Armstrong

"The surface is fine and powdery. I can pick it up loosely with my toe. It does adhere in fine layers like powdered charcoal to the sole and sides of my boots. I only go in a small fraction of an inch, but I can see the footprints of my boots and the treads in the fine particles."
Armstrong

"Roger, Tranquillity. We copy you on the ground. You got a bunch of guys about to turn blue. We're breathing again. Thanks a lot."
Duke

Mission control loses contact with Apollo 11

Alarms, loss of communication and system failures plagued the first mission to land on the Moon



03:04:15:47
"Apollo 11, Apollo 11, this is Houston. Do you read? Over."
Bruce McCandless, CAPCOM

03:04:15:59
"Apollo 11, Apollo 11, this is Houston. Do you read? Over."
Bruce McCandless, CAPCOM

03:04:16:11
"…"
Unidentified crew member, Apollo 11

03:04:16:59
"Houston, Apollo 11. Over."
Unidentified crew member, Apollo 11

03:04:17:00
"Apollo 11, Apollo 11, this is Houston. We are reading you weakly. Go ahead. Over."
Bruce McCandless, CAPCOM

03:04:19:32
"Apollo 11, this is Houston. Are you in the process of acquiring data on the burn? Over."
Bruce McCandless, CAPCOM

03:04:21:37
"Apollo 11, Apollo 11, this is Houston. How do you read?
Bruce McCandless, CAPCOM

03:04:21:43
"Reading you loud and clear, Houston. How us?
Neil Armstrong, Apollo 11 Commander

© Adrian Mann

was the first in the world to use integrated circuits. Its fixed memory was an ingeniously designed 'Core Rope', which consisted of a set of small hoops that 'Little Old Ladies' (as it was referred to at the time) along with machines would thread the code either through or around the hoops to give the computer its 1 or 0 value. If the MIT code was threaded incorrectly, the 'programmer' would have to laboriously go through the woven cores and debug it.

When the crew were approaching the Moon for the landing, various alarms were triggered by the computer. "Whatever information we were looking at [disappeared] and instead it gave us the code number of the alarm," said Aldrin. "It was disturbing and distracting and we didn't know what it meant."

The 1201 and 1202 alarms were obscure codes (and in effect the same error) that flashed up as Armstrong manually attempted to bring the Lunar Module down. Nobody seemed to know what the codes meant, except for two men: Jack Garman, a NASA computer engineer who had come across the codes before during a practice run, and Steve Bales, who was the Apollo guidance officer. The alarms were being caused by a problem with the landing radar that was stealing precious computing cycles, and the throttle control algorithm was barely working. The computer's 72kb of memory, barely enough to write a sentence in a modern word processor, was struggling as commands into it overflowed. Garman knew that it was safe to continue and allow the computer to handle matters. Its priority scheduling routines, which have formed some of the basis of a lot of modern code, were dumping lower priority tasks in favour of the ones critical to the lunar landing.

> "We started a stopwatch running, with a controller calling off seconds of fuel remaining" **Gene Kranz**

As the Eagle approached the surface on automatic, Armstrong and Aldrin realised that the scenery outside of the window didn't look familiar to them. "I think we may be a little long," commented Armstrong, referring to the Eagle having overshot its planned landing site. Looming ahead of them inside a crater was a dangerous-looking boulder field, and coming down on any of those giant rocks the size of houses would have damaged or perhaps even destroyed the Eagle. Armstrong took manual control, using the thrusters to take the Eagle over the boulder field. But now fuel was running low and there was no turning back. Armstrong had to land the Eagle – somewhere, within minutes – otherwise they would be out of fuel and crash.

"We'd never been this close in training," said Kranz. "We started a stopwatch running, with a controller calling off seconds of fuel remaining."

If things were tense in mission control, onboard the Eagle Armstrong and Aldrin had everything under control. With only 13 seconds of fuel left Apollo 11 made its safe landing in the Sea of Tranquillity. History had been made. "Houston, Tranquillity Base here," Armstrong radioed home. "The Eagle has landed."

In private, Aldrin took out a small cup, some wine and bread and said Holy Communion. The wine, under one-sixth Earth gravity, apparently curled up in the cup. After reading a section of the Gospel of St John, Aldrin said a few words, with Armstrong respectfully just looking on. NASA had been threatened with legal action by Madalyn O'Hair, an atheist, after the crew of Apollo 8 had read from the book of Genesis, so Aldrin's heartfelt ceremony never made it to the airwaves. Aldrin though has always been content in the thought that the first food and drink consumed on the lunar surface were communion items.

The original plan had been for the crew to get some sleep, but with that much adrenaline pumping through their veins that was never going to happen. So at 2.39am on the morning of 21 July, Armstrong made his way through the hatch and down the ladder before stepping foot for the first time on the surface of the Moon and saying those immortal words, "That's one small step for [a] man, one giant leap for mankind."

After exiting the Lunar Module, Armstrong and Aldrin only had a few hours to not only collect precious rock samples, but also deploy a series of experiments on the lunar surface. Solar wind experiments, a laser retro-reflector that is still used to this day to measure the Earth-Moon distance, seismometers, and more were all deployed. Armstrong is cited as saying he felt like a five year old in a candy store, with not enough time to do all the things he wanted to.

Standing on the Moon must have been an incredible experience. Aldrin described the scene around him as one of "magnificent desolation," adding that, "You could look at the horizon and see very clearly because there was no atmosphere, there was no haze or anything."

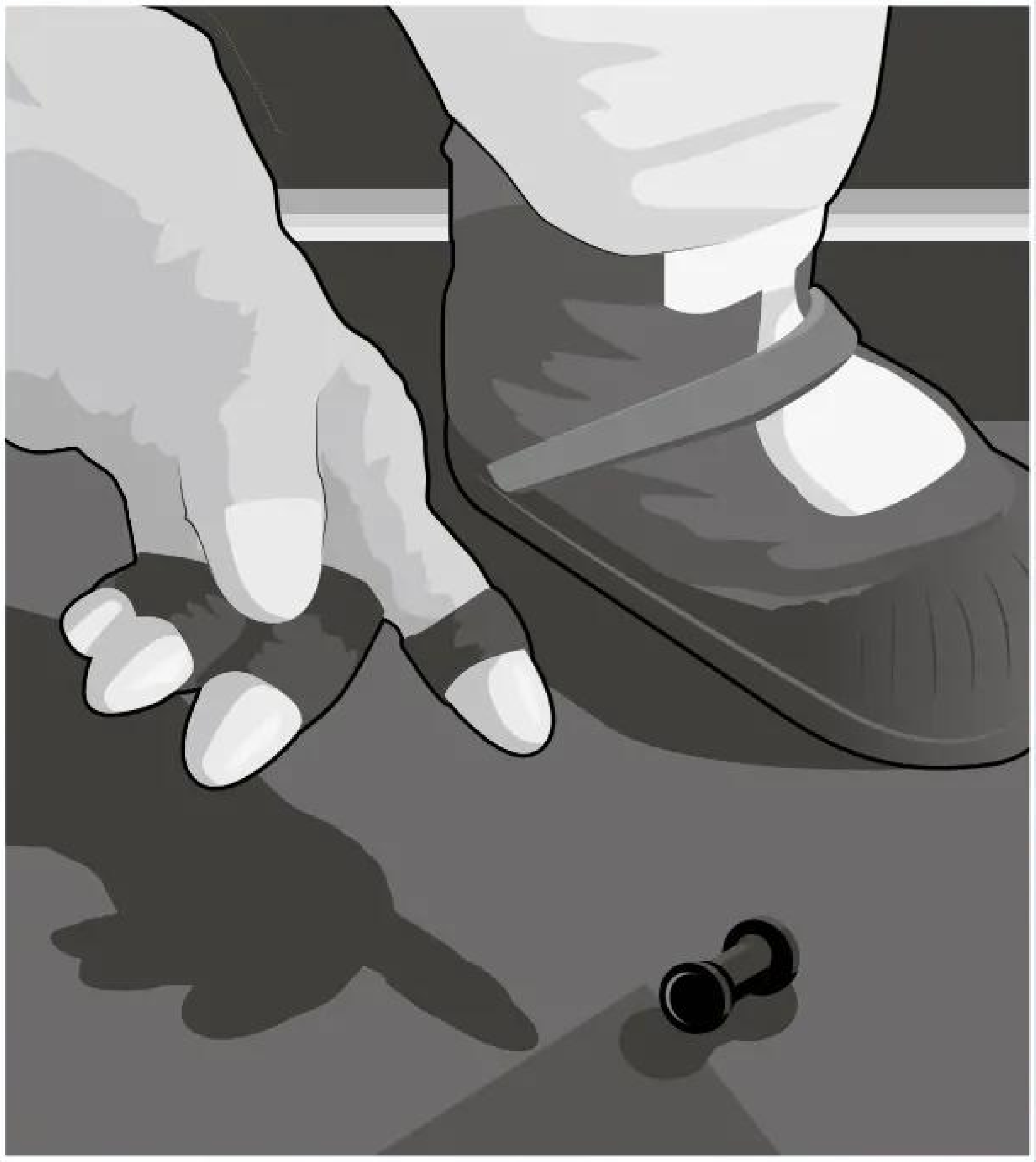
As Armstrong walked around setting up instruments and picking up rocks, Aldrin hopped around on the surface, testing what the best way to move about in the low gravity was. Most of the pictures taken during the landing are of Aldrin on the surface; barely half a dozen show Armstrong, and none clearly. That's because Armstrong had the camera for most of the Moon walk.

While on the surface, the crew also had terrific problems with the American flag. It had a telescoping boom arm to hold it out in lieu of any wind to hold it up. The two crew wrestled to get the boom arm to extend fully, but it would not, so the flag had a small kink in it. They also found that it was almost impossible to get the flag pole to go deep enough into the ground and, in the end, they only just managed to get it to stay upright. Both of the crew worried it would fall over live on TV, and

HOW TO...

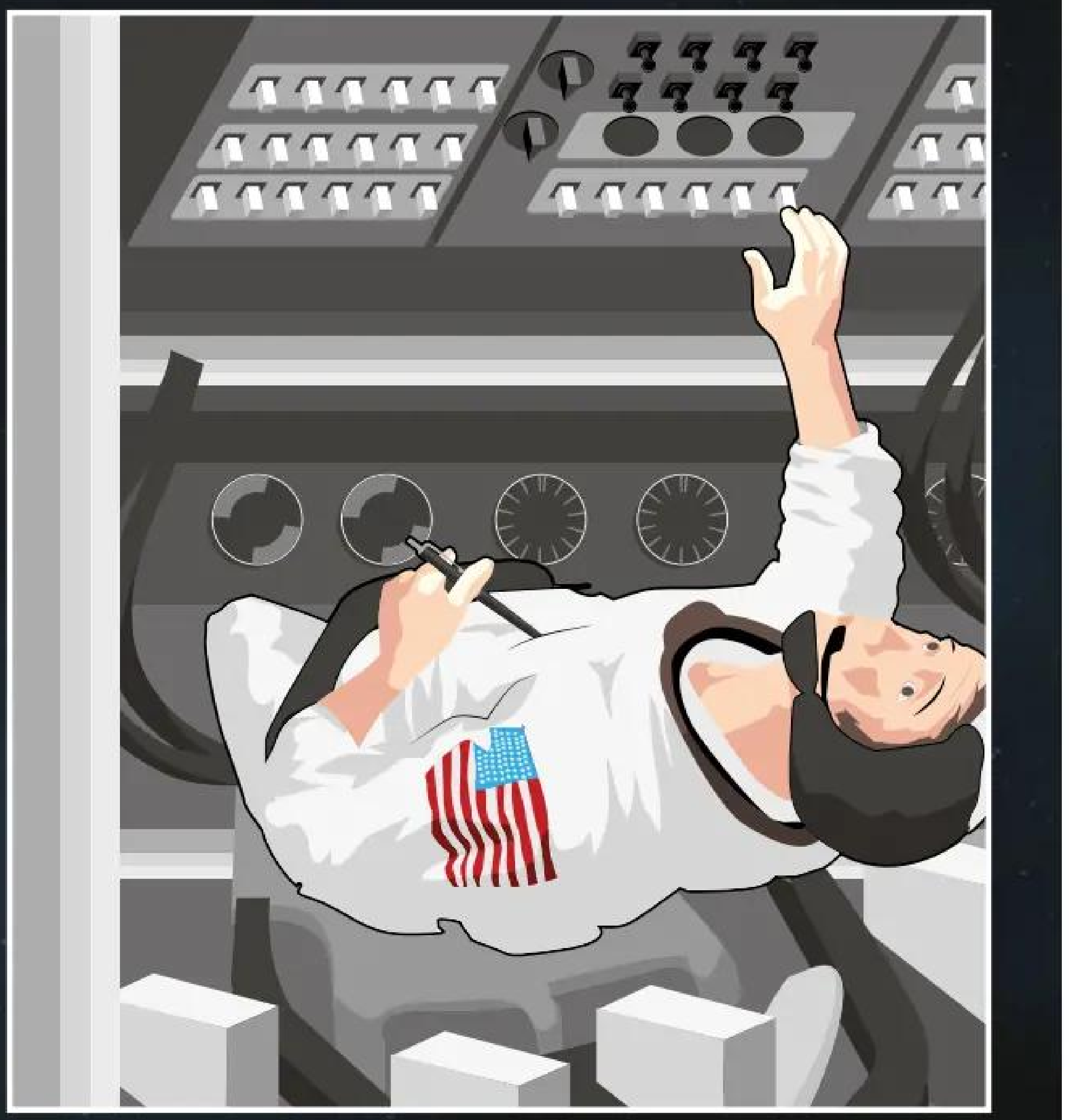
Use a felt-tipped pen to escape from the Moon

After a circuit breaker switch broke off in all the too-ing and fro-ing in the cramped environment of the lunar module, Buzz Aldrin had to improvise in order to escape the Moon



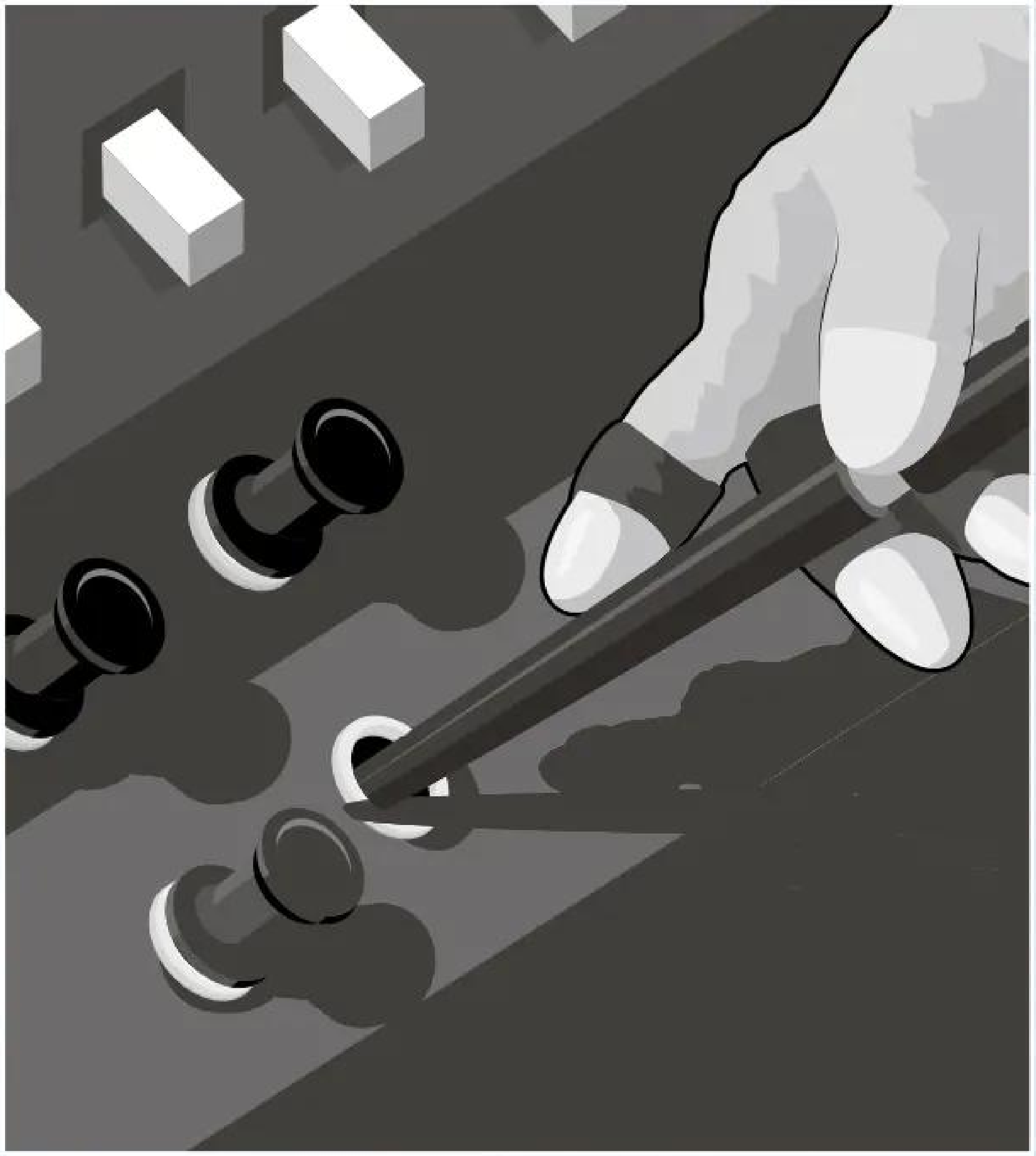
1 Astronauts locate broken circuit breaker switch

Neil Armstrong and Buzz Aldrin were gathering themselves into the landing module to start the return back to Earth when Aldrin noticed something lying on the floor – the circuit breaker switch had gotten bumped and had broken off.



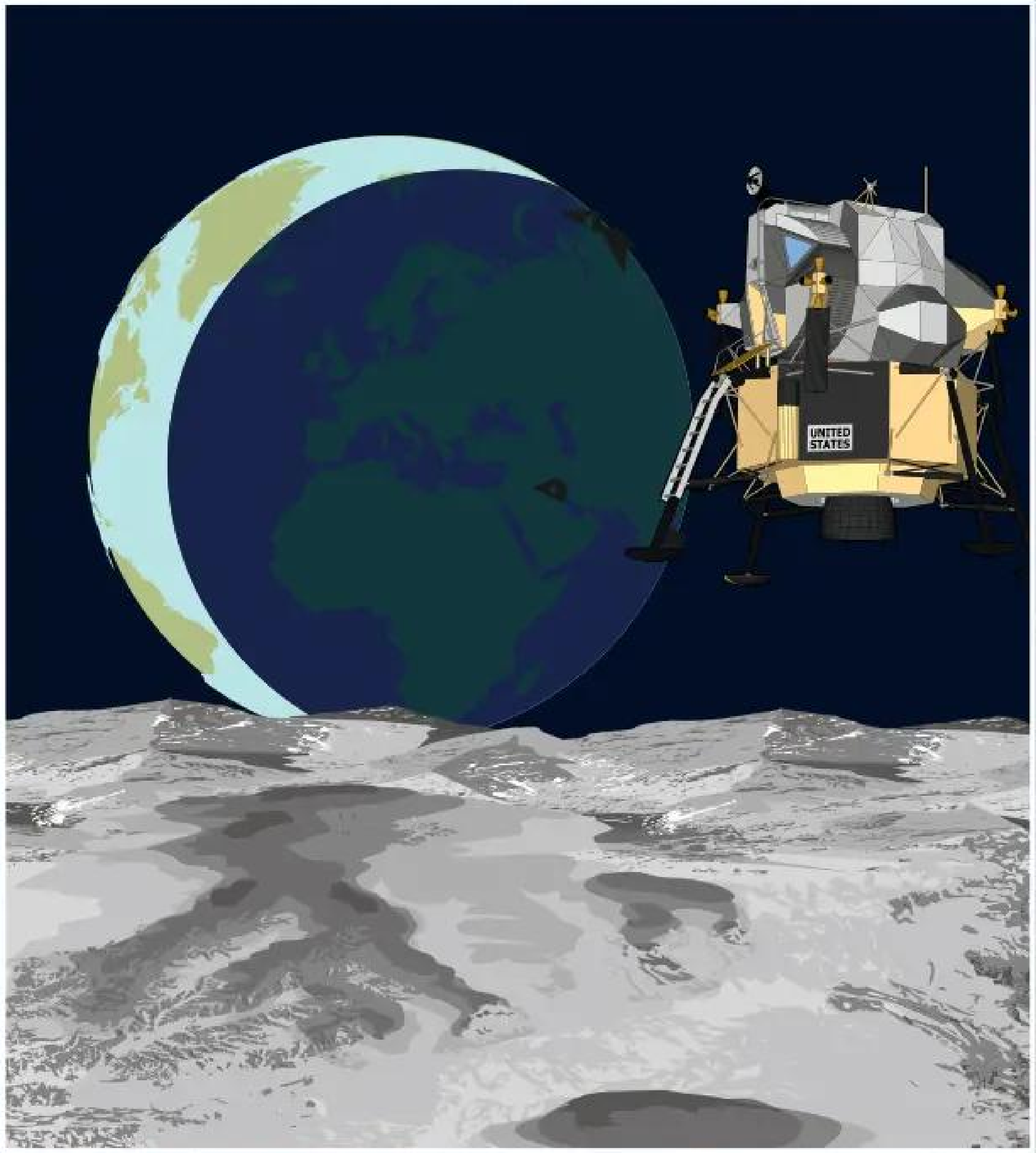
2 Aldrin and Armstrong alert mission control

This switch needed to activate the ascent engine to lift them off the Moon. Telling mission control, they tried unsuccessfully to catch some sleep but, by the following morning, NASA had no solution with Aldrin forced to come up with a solution.



3 Saved by a felt-tipped pen

Since the circuit was electrical, sticking his finger or anything metal in wasn't possible. Instead, Aldrin found a felt-tipped pen in his shirt and inserted it into the opening where the circuit breaker switch should have been. He moved the countdown procedure up by a couple of hours.



4 Lift off!

The circuit breaker held, allowing both Aldrin and Armstrong to lift off from the surface of the Moon and intercept Michael Collins, who was in orbit around the Moon.

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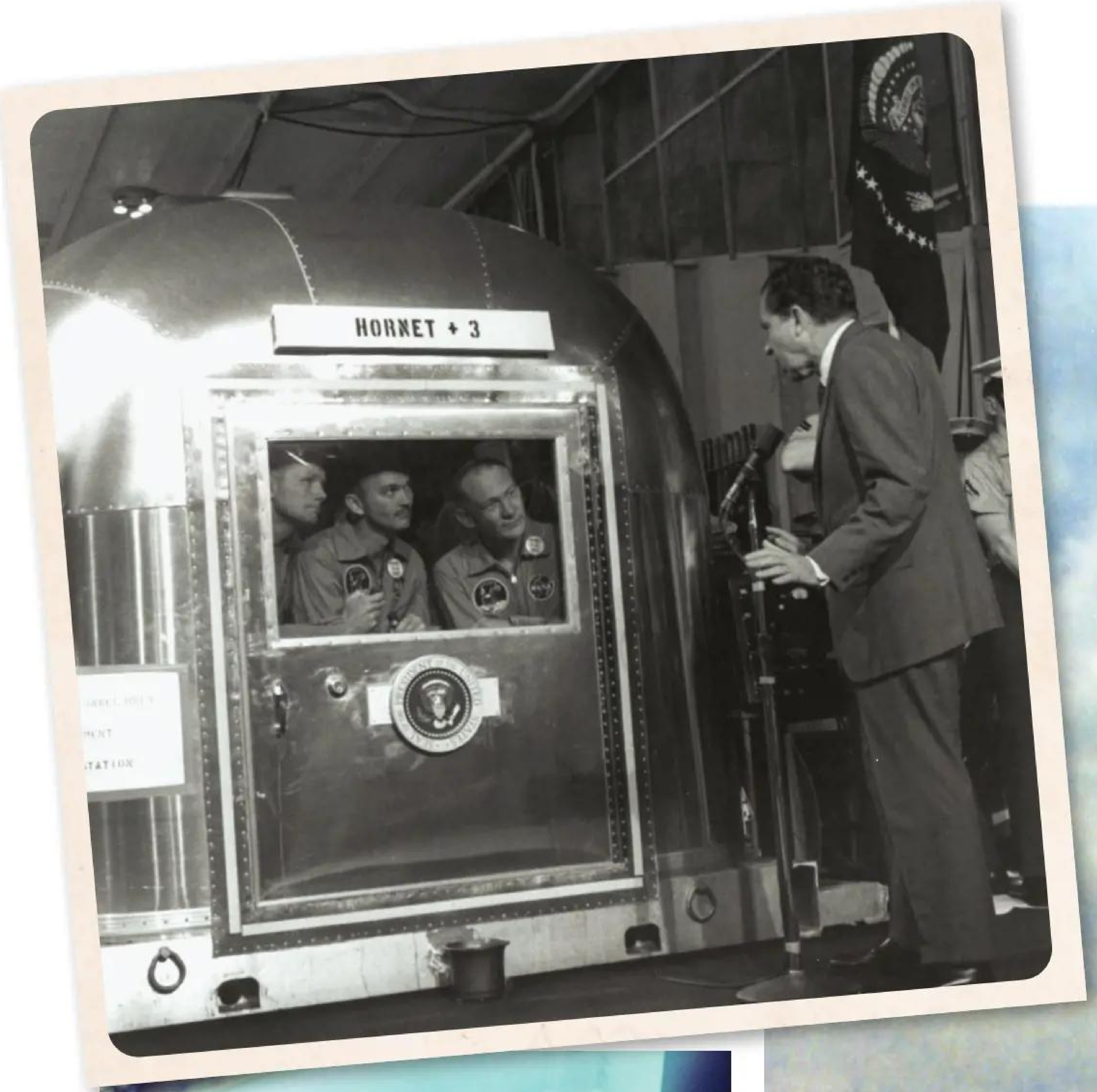
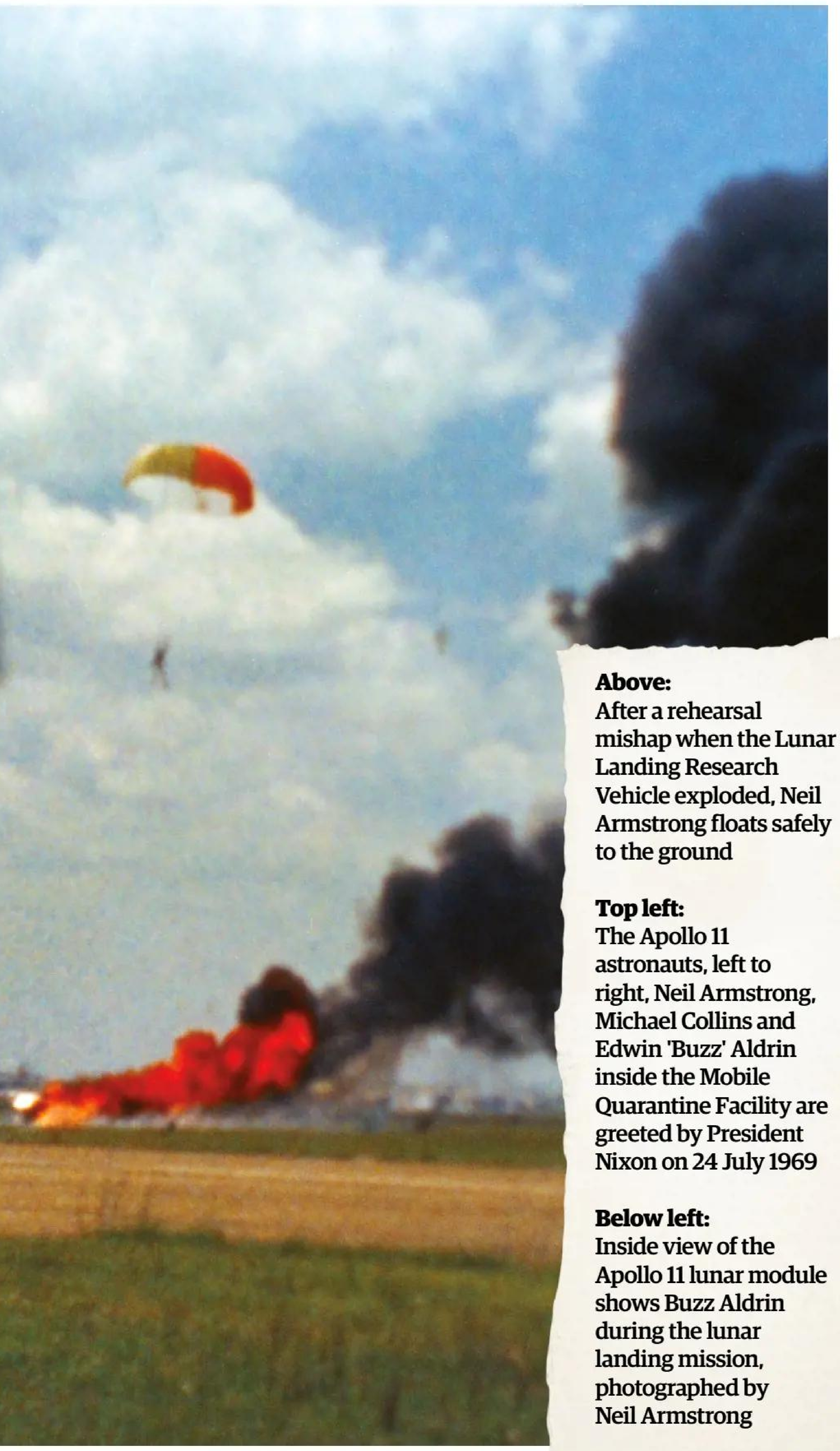
Left:
The huge, 111-metre (363-foot) tall Saturn V rocket carries three men towards the Moon from Pad A, Launch Complex 39, Kennedy Space Center on 16 July 1969





Above:
After a rehearsal mishap when the Lunar Landing Research Vehicle exploded, Neil Armstrong floats safely to the ground

Top left:
The Apollo 11 astronauts, left to right, Neil Armstrong, Michael Collins and Edwin 'Buzz' Aldrin inside the Mobile Quarantine Facility are greeted by President Nixon on 24 July 1969

Below left:
Inside view of the Apollo 11 lunar module shows Buzz Aldrin during the lunar landing mission, photographed by Neil Armstrong

probably as President Nixon was on the phone to them. But it remained upright during the broadcasts and telephone calls.

After collecting their rocks and clambering back into the Lunar Module, the crew took off their boots and backpacks, and began to throw anything not of vital importance back on to the lunar surface. This included urine bags, empty food packs, empty cameras and so on. But to the crew, they were just getting in the way and not needed.

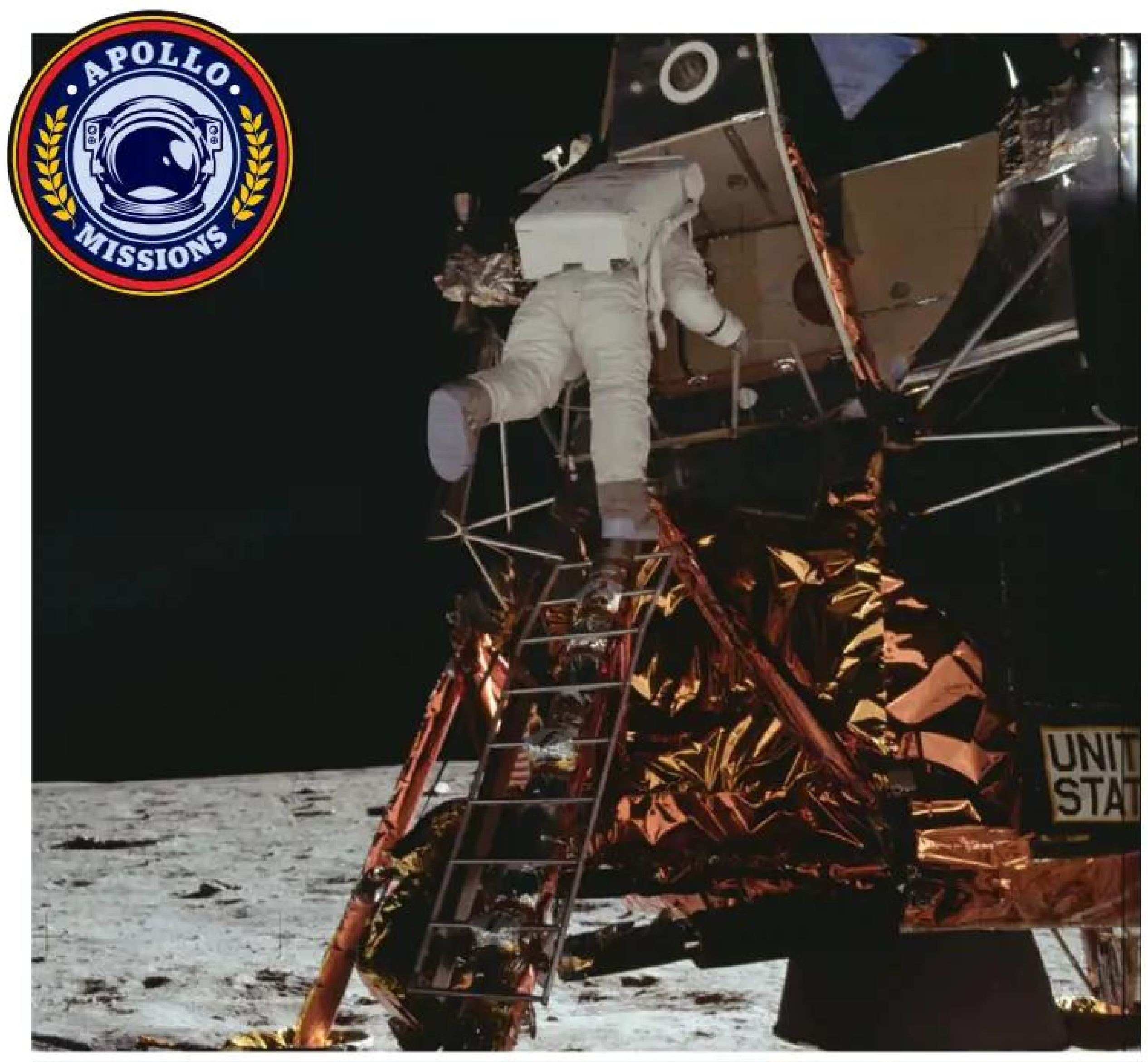
There was time for one final crisis. The interior of the Lunar Module was cramped and, moving around in their bulky spacesuits, one of the astronauts had knocked out the switch for the circuit breaker that fired the ascent rocket that would take them home.

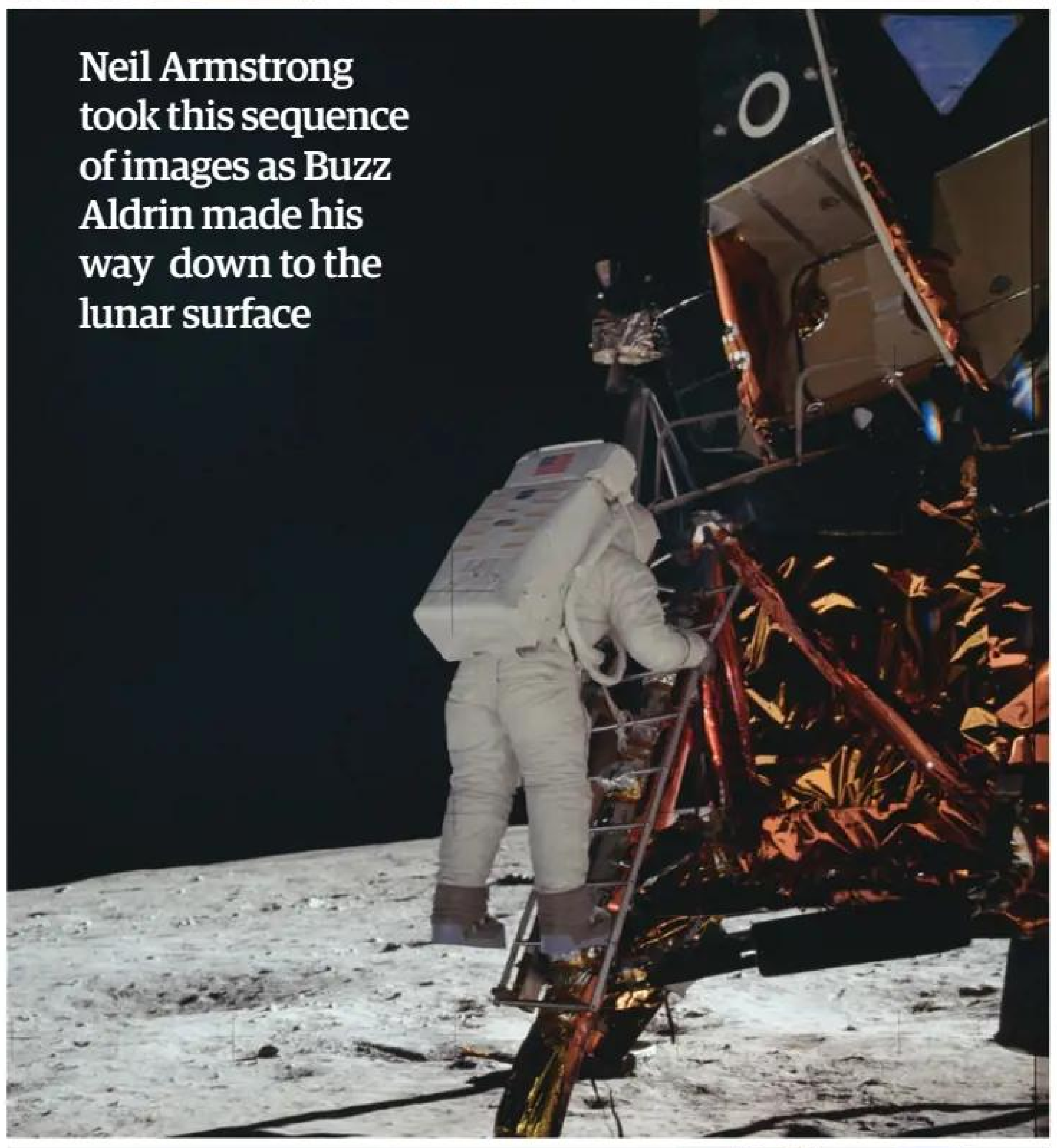
This was a real bottleneck moment for the mission. "If for some reason the ascent engine didn't work, there was no way to rescue the crew," said Kranz. Armstrong and Aldrin would be stranded on the Moon. The concern was so serious that President Nixon had a speech prepared, while mission control would close down communications with Armstrong and Aldrin after a clergyman had "condemned their souls to the deepest of the deep." Without that circuit breaker the crew were facing that lonely fate, but their training would not have allowed them to give up. "Rather than worry about things like that, we'd face them when the time came and we'd work as hard as we could to fix the problem until our oxygen ran out," said Aldrin.

> "If for some reason the ascent engine didn't work, there was no way to rescue the crew" **Gene Kranz**

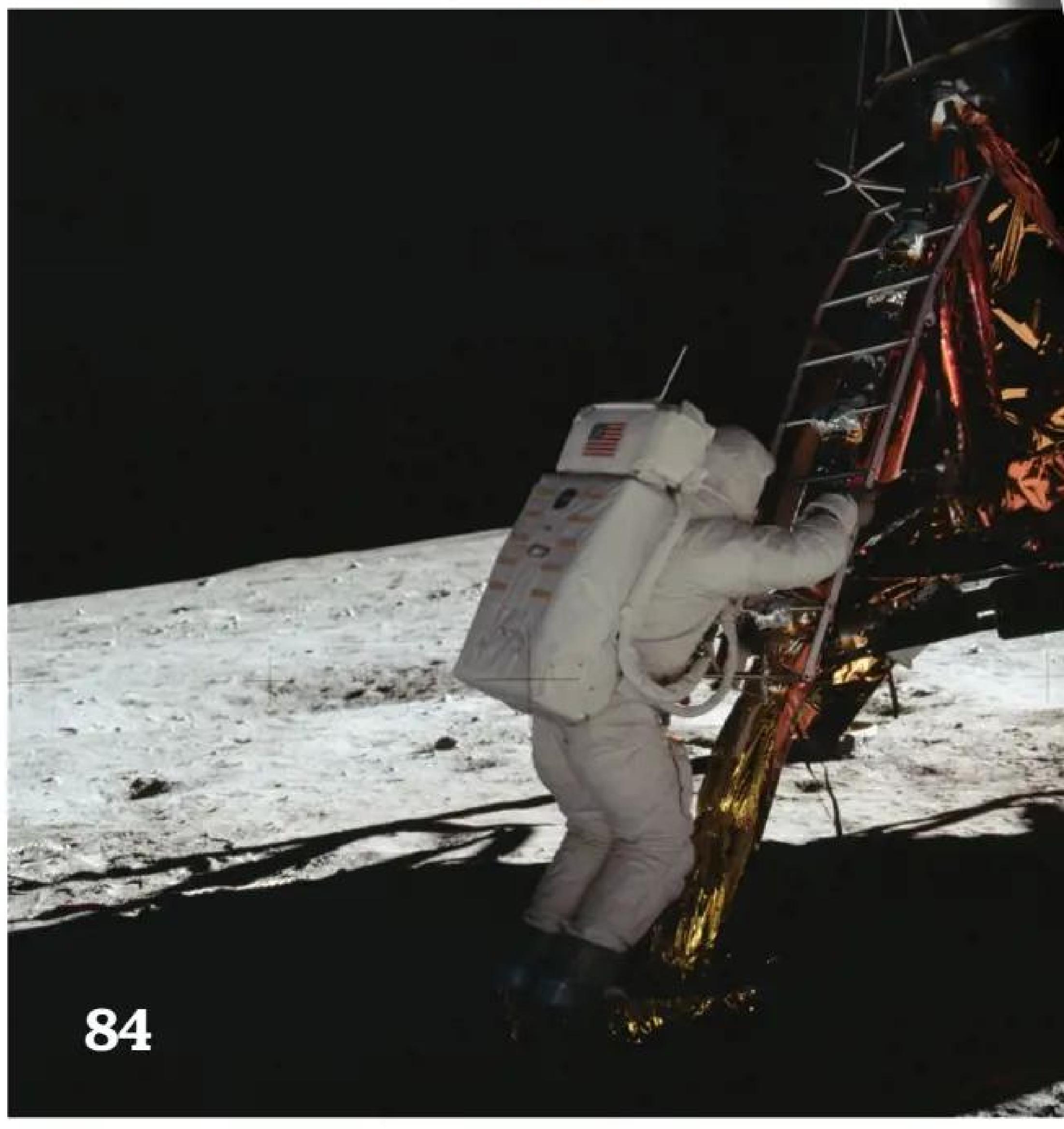
In the end, the solution was remarkably simple. Jabbing the end of a pen into the slot where the broken switch had been, Aldrin was able to push the circuit breaker in. The ascent rocket fired and the two Moon-walkers were on their way home, via a rendezvous with Michael Collins in the Command Module. As the Eagle took off, the flag finally did blow over, and to this day it lays flattened, bleached out by solar radiation.

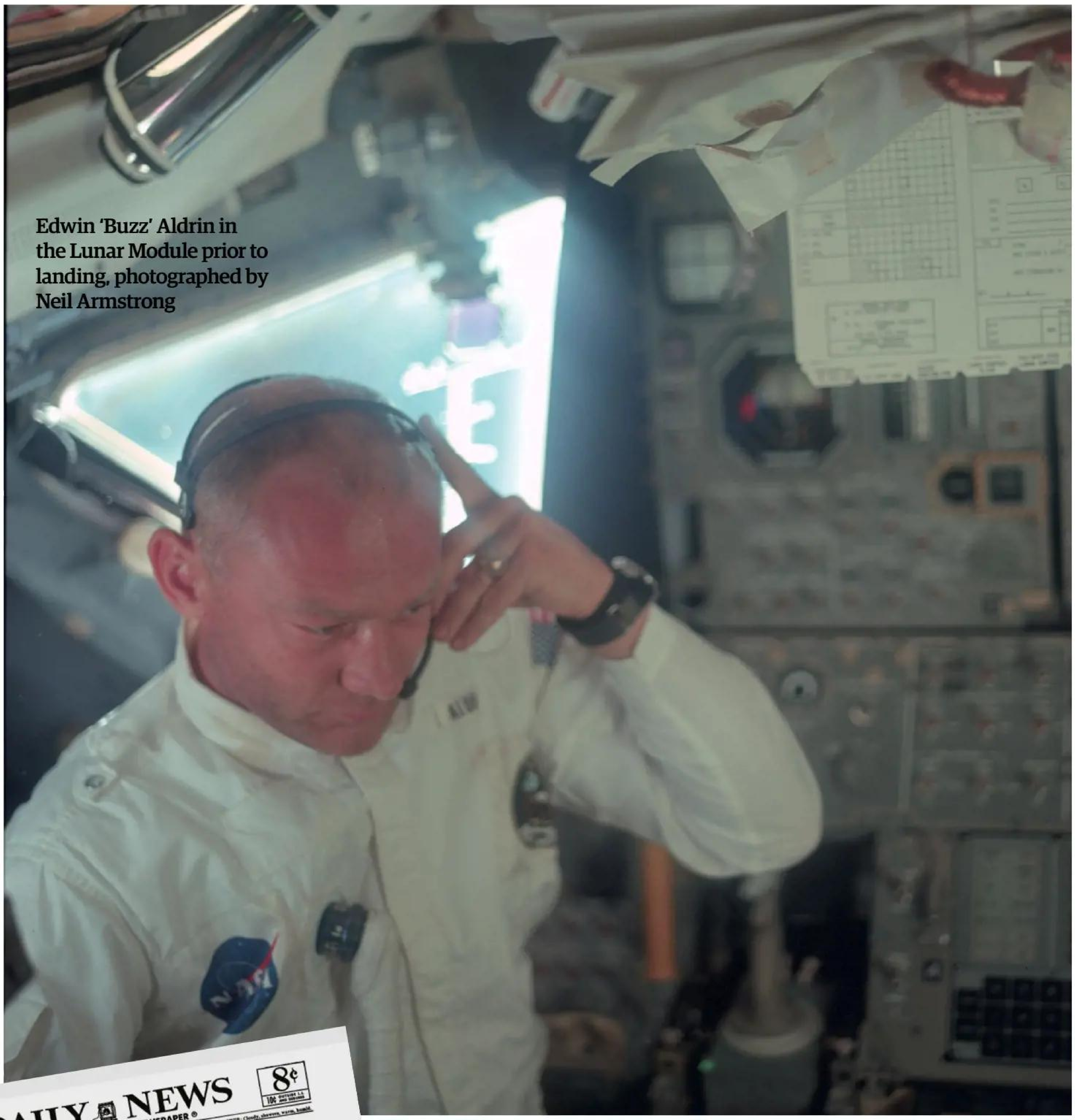
Over 50 years since that first successful landing on the Moon, stories still come out, not just from the thoughts of the crew, but also the almost 400,000 others who worked on the mission, from 'the guy sweeping the floor' at Cape Canaveral, to the flight directors and flight controllers still, without whom the historic landing may never have happened. With our return to the Moon still some way off, these stories are all we have for now.



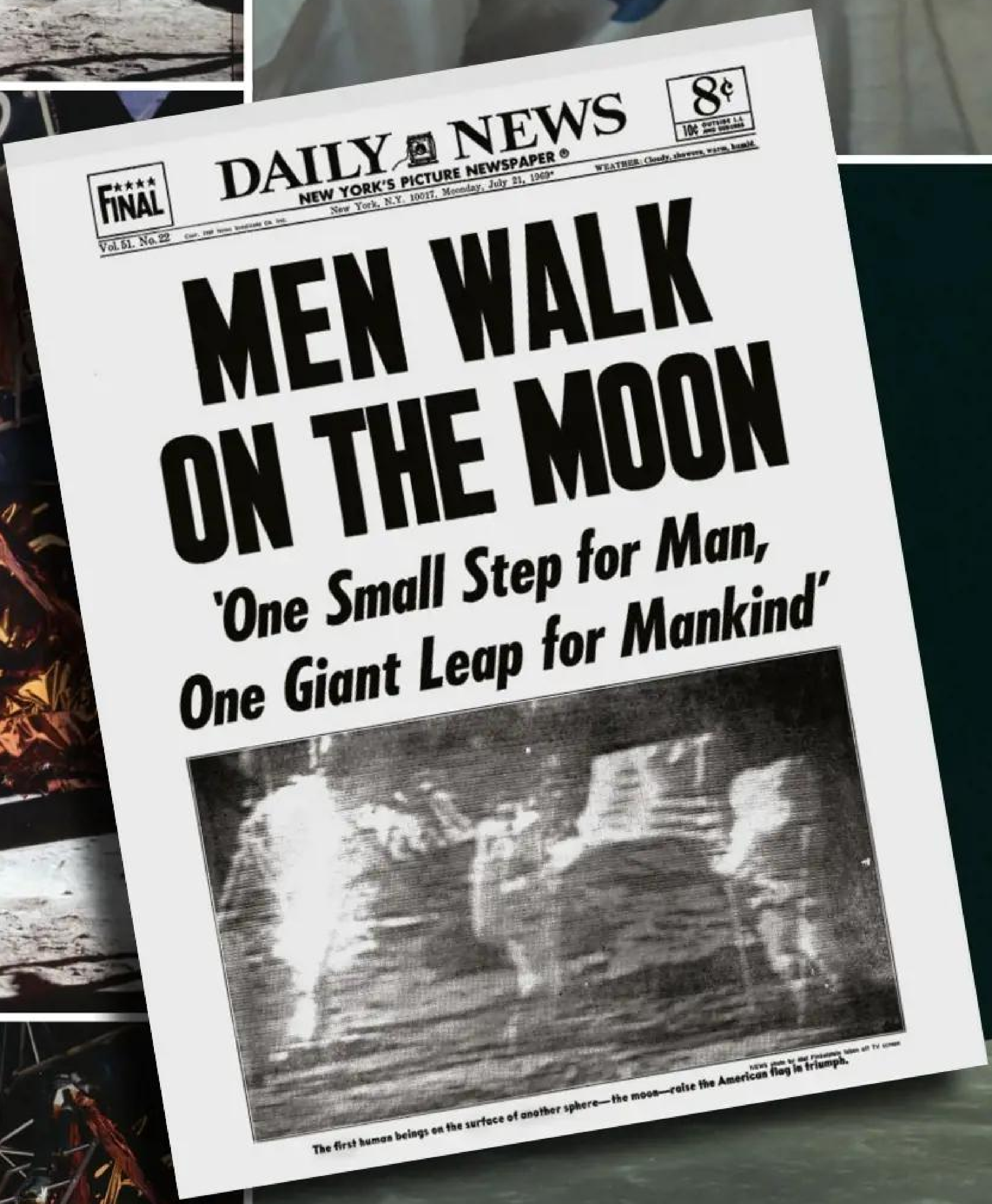


Neil Armstrong took this sequence of images as Buzz Aldrin made his way down to the lunar surface





Edwin 'Buzz' Aldrin in the Lunar Module prior to landing, photographed by Neil Armstrong



DAILY NEWS

NEW YORK'S PICTURE NEWSPAPER ®

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FINAL

Vol. 51. No. 22

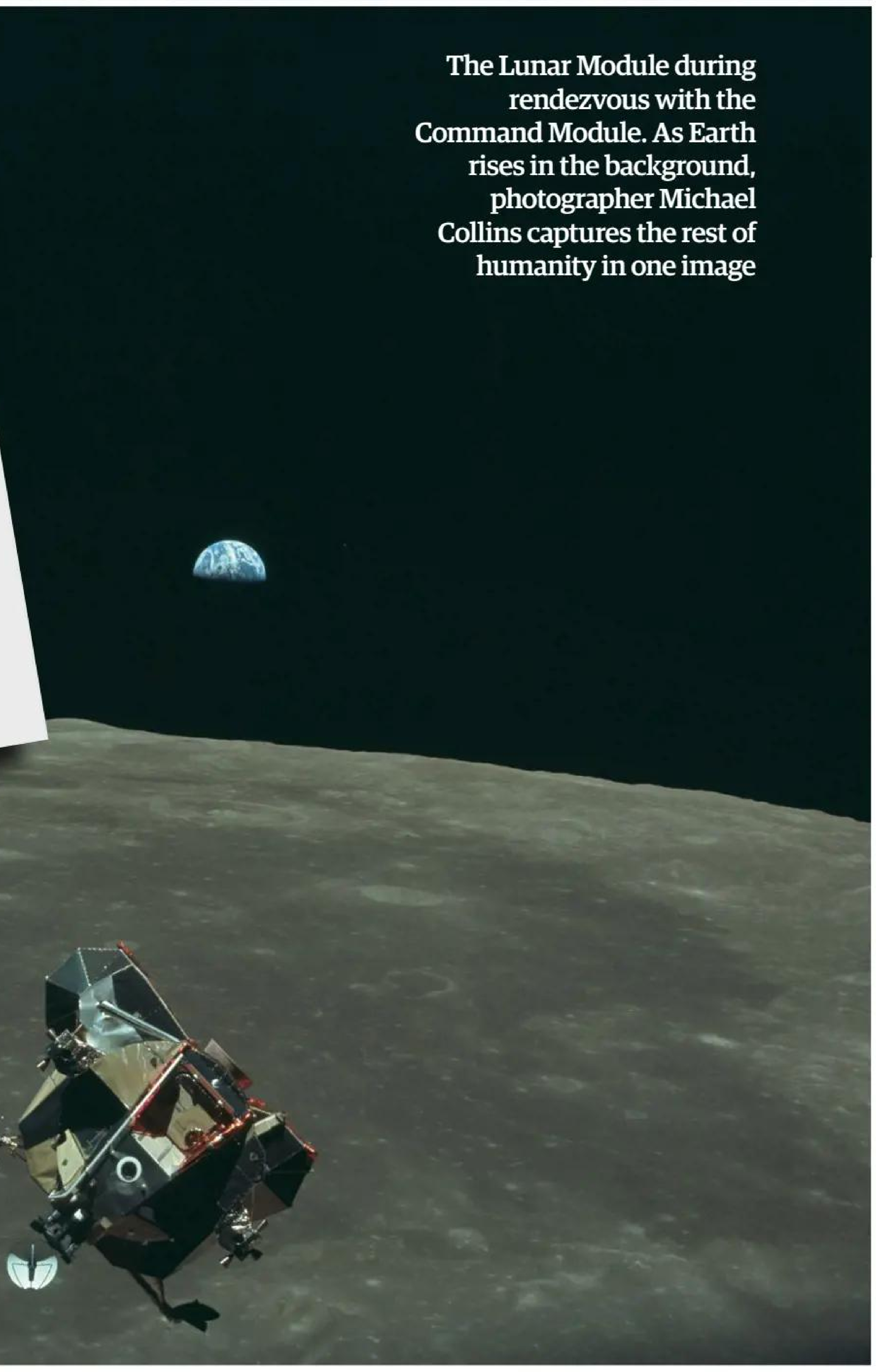
8¢

WEATHER: Cloudy, showers, warm, humid.

MEN WALK ON THE MOON

'One Small Step for Man, One Giant Leap for Mankind'

The first human beings on the surface of another sphere—the moon—raise the American flag in triumph.



The Lunar Module during rendezvous with the Command Module. As Earth rises in the background, photographer Michael Collins captures the rest of humanity in one image

Command Module pilot Michael Collins, pictured during simulation training at the Kennedy Space Center

A shot of Armstrong still wearing his suit's 'Snoopy' cap in the Lunar Module, taken by Aldrin after their EVA

A close-up of Buzz Aldrin creating a bootprint, to record the mechanics of lunar soil

©Images NASA

Charles Conrad unfurls the US flag during his first EVA on 19 November 1968

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NASA's second lunar landing was all about precision

APOLLO 12

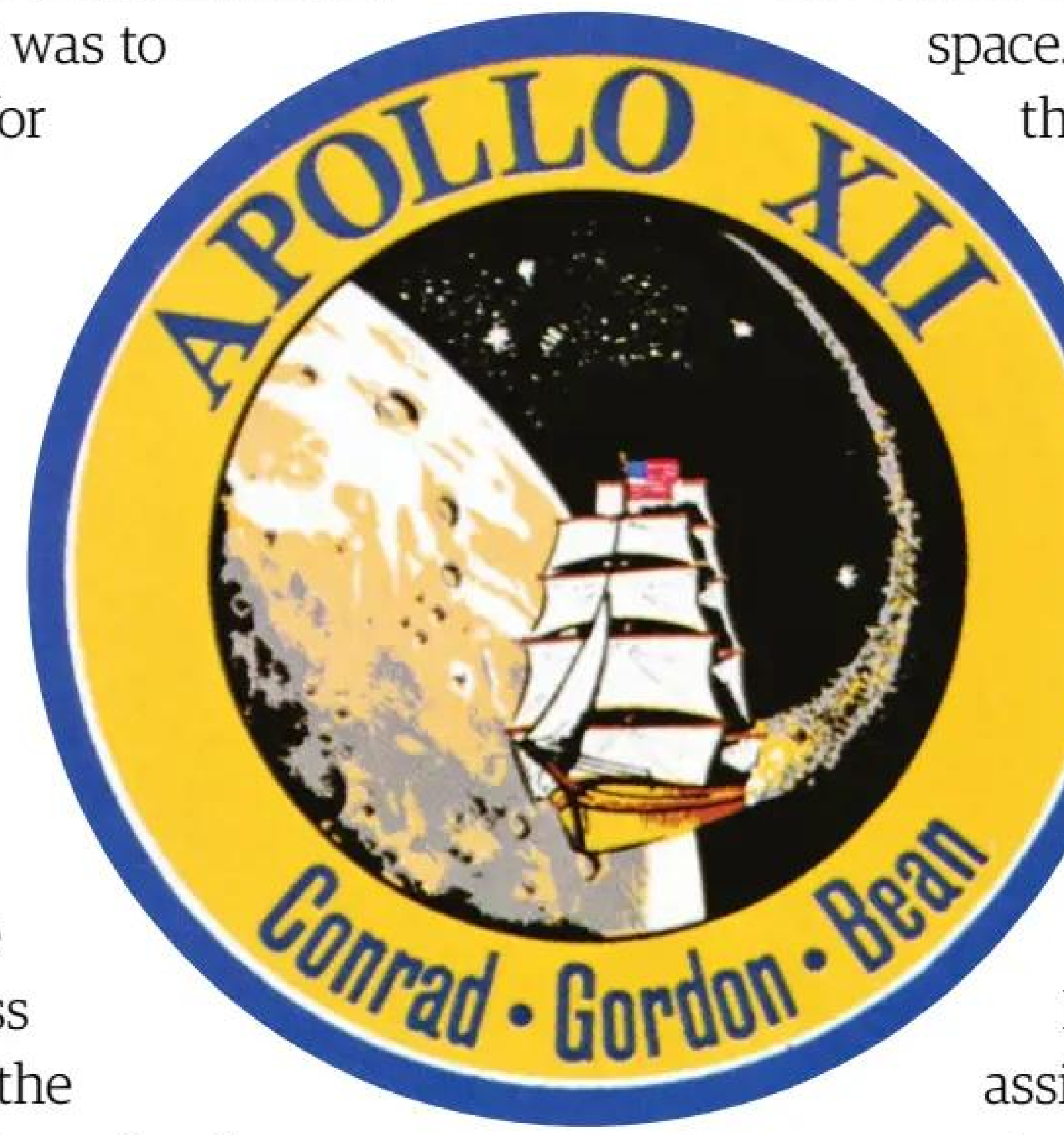
The Pinpoint Mission

Reported by Elizabeth Howell

Apollo 12 was the second crewed mission to land on the Moon. The mission lifted off on 14 November 1969, a little less than four months after two members of the Apollo 11 crew became the first people to walk on the moon. The target for Apollo 12 was a large basaltic plain on the Moon's surface called the Ocean of Storms. Like its predecessor mission, the primary goal for Apollo 12 was to explore the area and prepare for future landing missions.

The Apollo 12 mission had several memorable moments, the first of which was landing on target. That didn't happen during Apollo 11, in part because Commander Neil Armstrong needed to steer around boulders on the surface to find a safe landing spot. Some accounts also claim that excess oxygen in the hatch between the spacecraft pushed Apollo 11's lunar lander (the Lunar Module) off course when it undocked from the Command Module.

The Apollo 12 mission is also remembered for surviving two lightning strikes during launch and for the strong camaraderie of its three astronauts, who were close friends before they were selected as a crew.

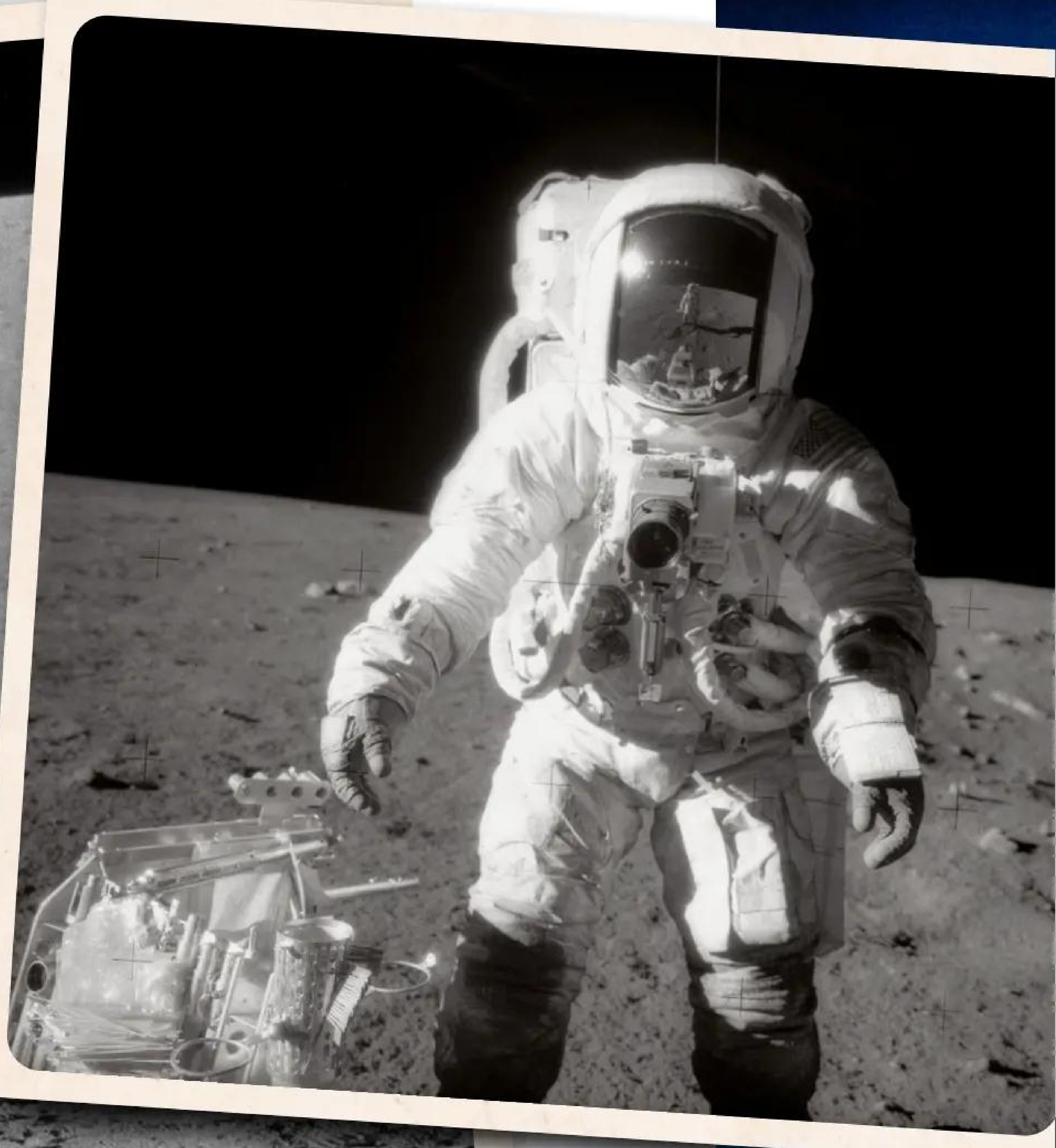


Apollo 12 flight crew

Prior to joining NASA in 1962, Cmdr Pete Conrad graduated from Princeton University and joined the US Navy, where he was a flight instructor. He took his first space flight on Gemini 5, in 1965, which set an endurance record at the time (eight days in space). That mission also pushed the US ahead of the Soviet Union in accumulated hours in space. Conrad additionally commanded the Gemini 11 mission in 1966.

After Apollo 12, he commanded the first mission to space station Skylab, in 1973, and participated in several tricky spacewalks to restore the space station, which was badly damaged at launch.

Lunar module pilot Alan Bean was a student of Conrad's at the US Naval Test Pilot School before joining NASA in 1963. One of his first assignments for NASA was to work on missions after the Moon landings. In interviews for journalist Andrew Chaikin's 1994 book *A Man on the Moon*, astronauts said that Bean was Conrad's first pick for Apollo 12, but CC Williams, a rookie astronaut, earned the spot instead. Tragically, Williams died when his Northrop T-38 Talon supersonic jet crashed on 5 October 1967. Conrad again asked NASA to bring



Above: The Surveyor 3 lander - which launched in April 1967 - got a visit from the Apollo 12 crew in 1969

Above right: A portrait of Alan Bean during an EVA, taken by Pete Conrad, whose reflection is visible in Bean's visor

Right: Apollo 12's flag had a faulty latch mechanism, so it did not stay horizontal

Bean on board, and the agency agreed. Bean went on to command the second Skylab mission, in 1973.

The command module pilot for Apollo 12 was Richard 'Dick' Gordon, who came to NASA in 1963 after setting flight speed and distance records and performing test flights for the Navy. His skill in the pilot's chair came in handy for the Gemini 11 mission, when he and Conrad piloted the docked spacecraft to 1,373 kilometres (853 miles) above Earth, an altitude record at the time. Apollo 12 was Gordon's last spaceflight.

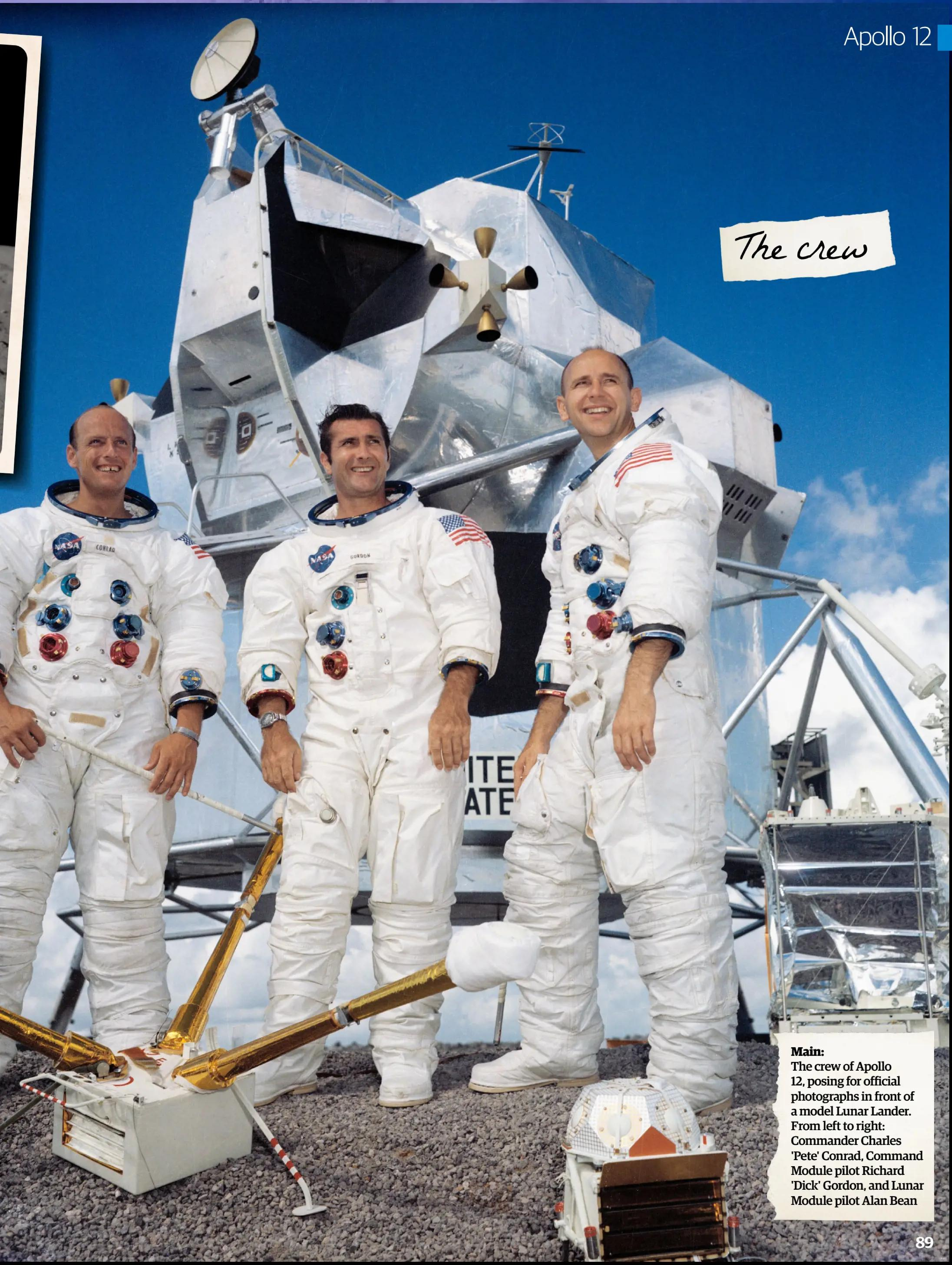
Kicking up dust in the Ocean of Storms

Lightning struck Apollo 12's rocket, a Saturn V, twice during the launch. While the astronauts had some trouble with the displays on board after the lightning strikes, the rocket remained functional and placed the spacecraft in its target orbit around Earth. NASA carefully evaluated the risks of the mission after the lightning strikes, and decided it was safe enough to proceed to the Moon (Several biographies say the agency later revised the launch safety rules to protect future spacecraft from lightning strikes).

The command module, Yankee Clipper, and lunar module, Intrepid, safely arrived at the Moon on 18 November. As planned, Gordon remained behind in Yankee Clipper while Conrad and Bean went into Intrepid for their trip to the lunar surface. During landing, Conrad and Bean anxiously looked outside, hoping that what they saw on the surface would correspond with what they had memorised from maps while back on Earth. When Conrad spotted a familiar crater, he whooped, "There it is! Son of a gun, right down the middle of the road!"

The planned landing point was too rocky for Conrad's taste, so he took the command stick in

The crew



Main:
The crew of Apollo 12, posing for official photographs in front of a model Lunar Lander. From left to right: Commander Charles 'Pete' Conrad, Command Module pilot Richard 'Dick' Gordon, and Lunar Module pilot Alan Bean

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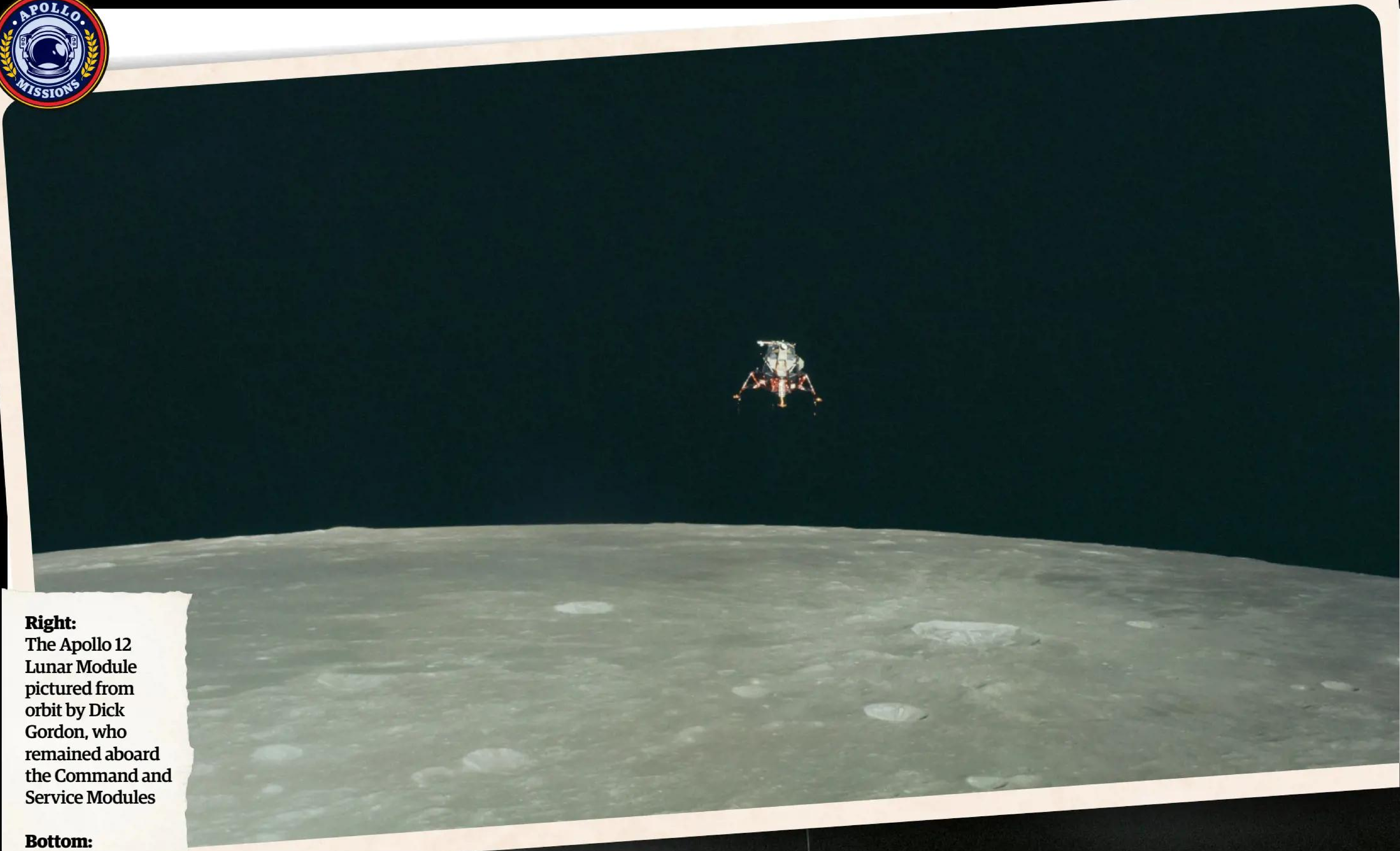
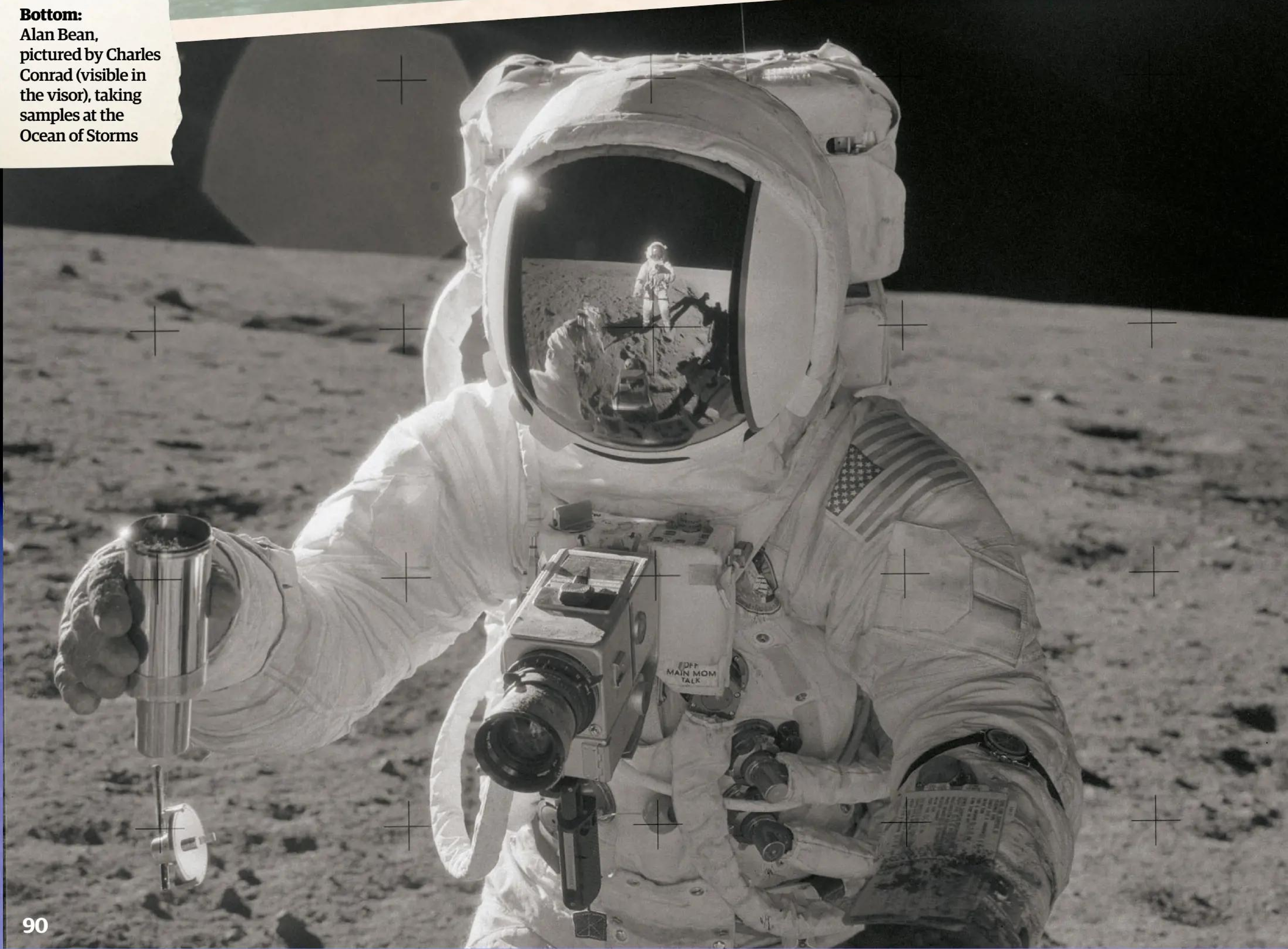


Right: The Apollo 12 Lunar Module pictured from orbit by Dick Gordon, who remained aboard the Command and Service Modules



Bottom: Alan Bean, pictured by Charles Conrad (visible in the visor), taking samples at the Ocean of Storms

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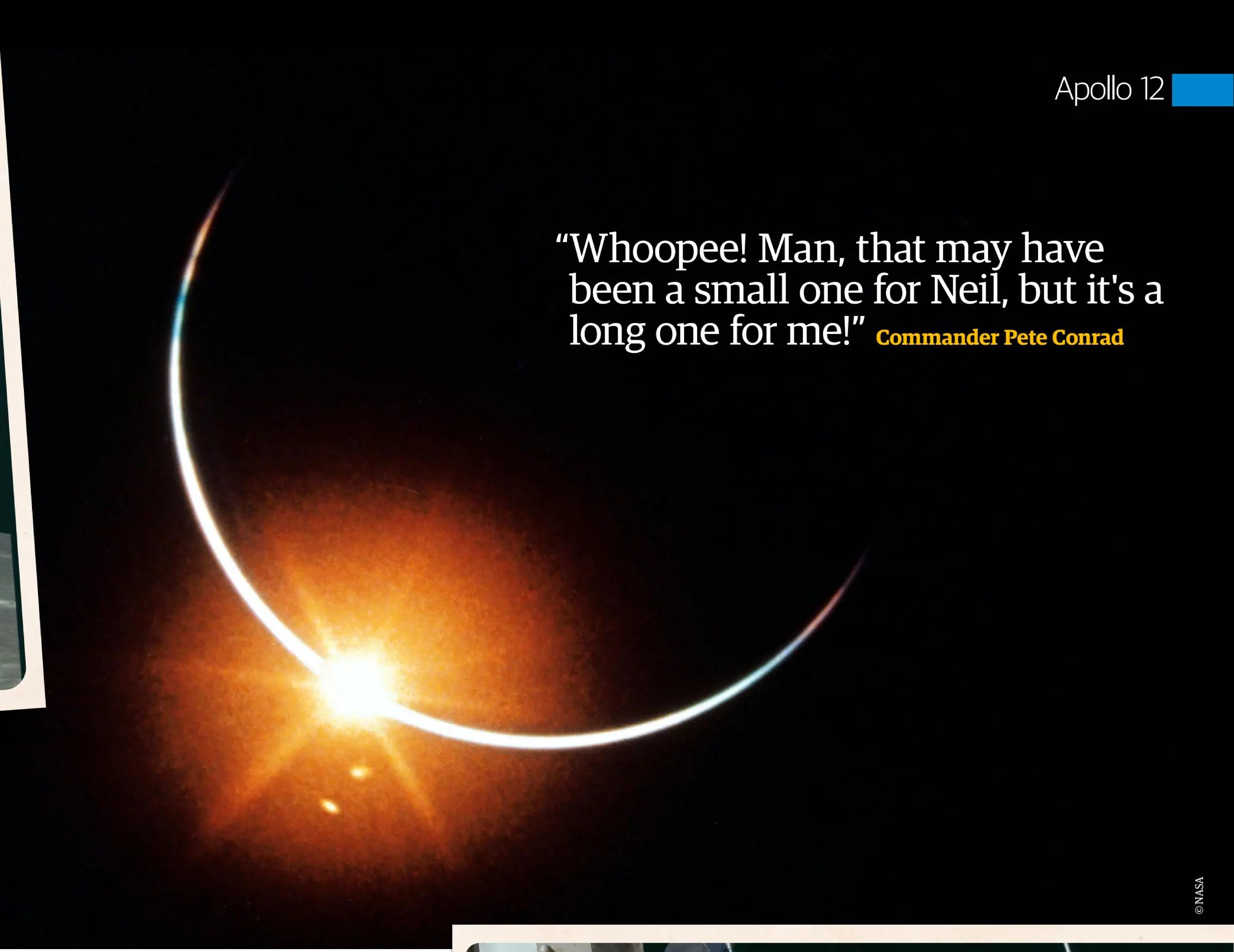


"Whoopee! Man, that may have been a small one for Neil, but it's a long one for me!" **Commander Pete Conrad**

© NASA

hand and carefully steered his way to an alternate landing site.

Intrepid's descent stirred up a large dust cloud on the lunar surface as the astronauts glided into the Ocean of Storms. Conrad landed with little fuel to spare, and within shouting distance of Surveyor 3, a robotic spacecraft that had landed on the Moon more than two years earlier.

When it was time for Conrad to head down the ladder to the surface a few hours later, he joked about his height (5 feet, 6 inches tall, as opposed to Neil Armstrong's 5 feet, 11 inches): "Whoopee! Man, that may have been a small one for Neil, but it's a long one for me."

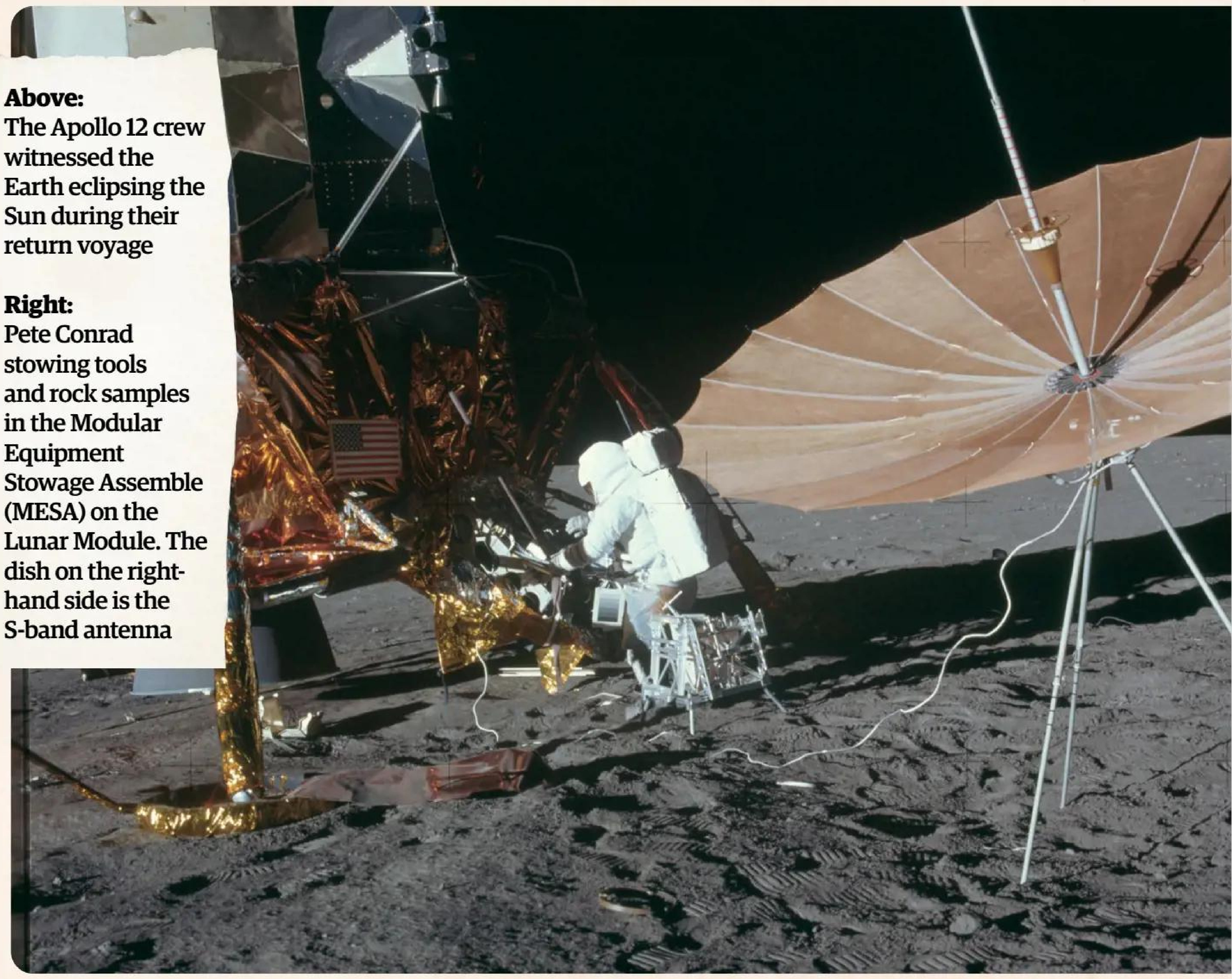
Apollo 12 legacy

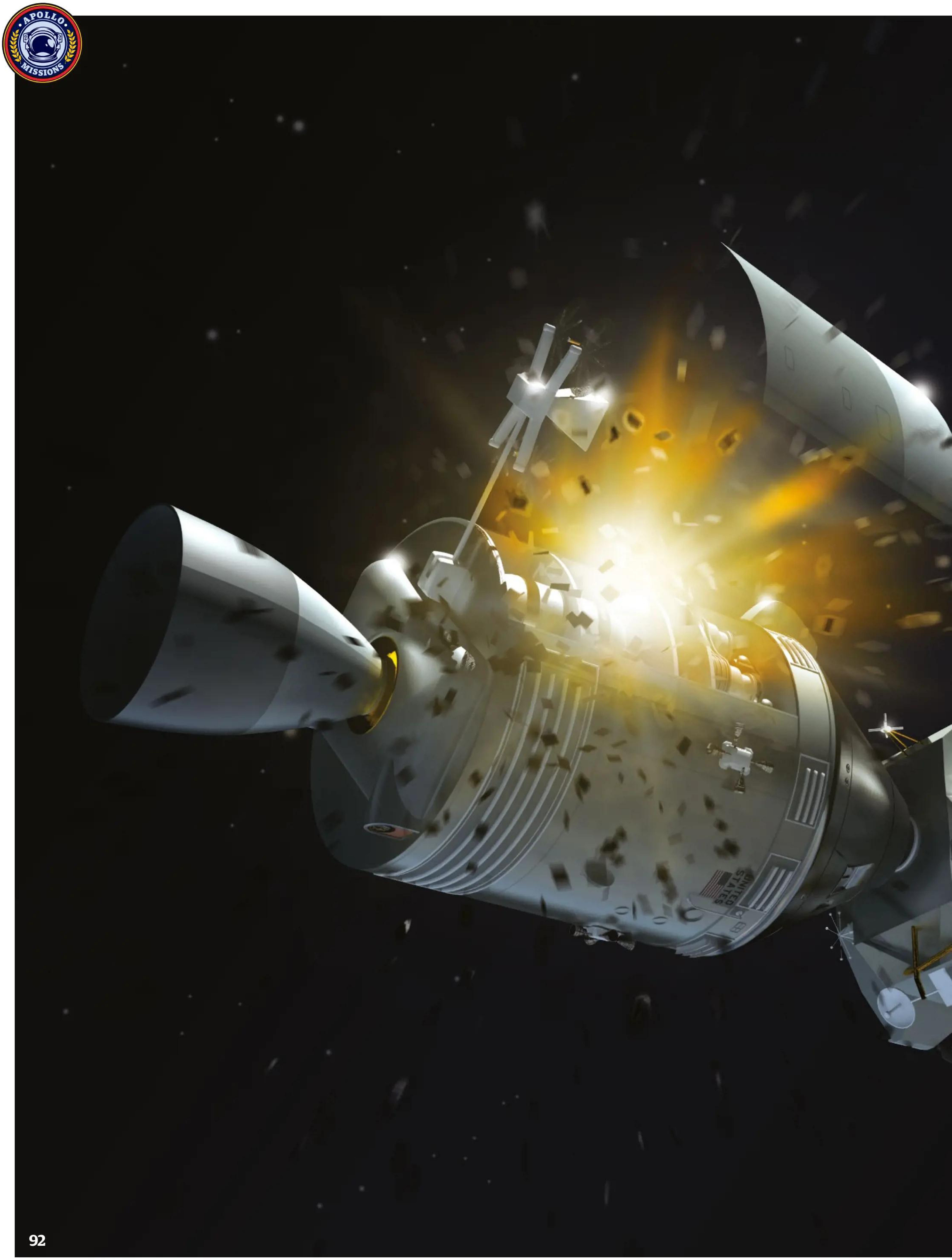
The Yankee Clipper is on display at the Virginia Air and Space Center in Hampton, Virginia. Intrepid's upper stage, which carried the astronauts back to Yankee Clipper, no longer exists, as it crashed into the moon on 20 November 1969. Apollo 12's 50th anniversary is in November 2019.

The Apollo 12 crew, who were close friends, were always disappointed that Gordon never got the chance for a moonwalk. Years later, Bean – in his next career, as an artist – did a painting portraying Gordon, Bean and Conrad on the surface of the Ocean of Storms. Bean titled the piece 'The Fantasy', one of a series of paintings showing "buddies forever" on the Moon.

Above:
The Apollo 12 crew witnessed the Earth eclipsing the Sun during their return voyage

Right:
Pete Conrad stowing tools and rock samples in the Modular Equipment Stowage Assemble (MESA) on the Lunar Module. The dish on the right-hand side is the S-band antenna





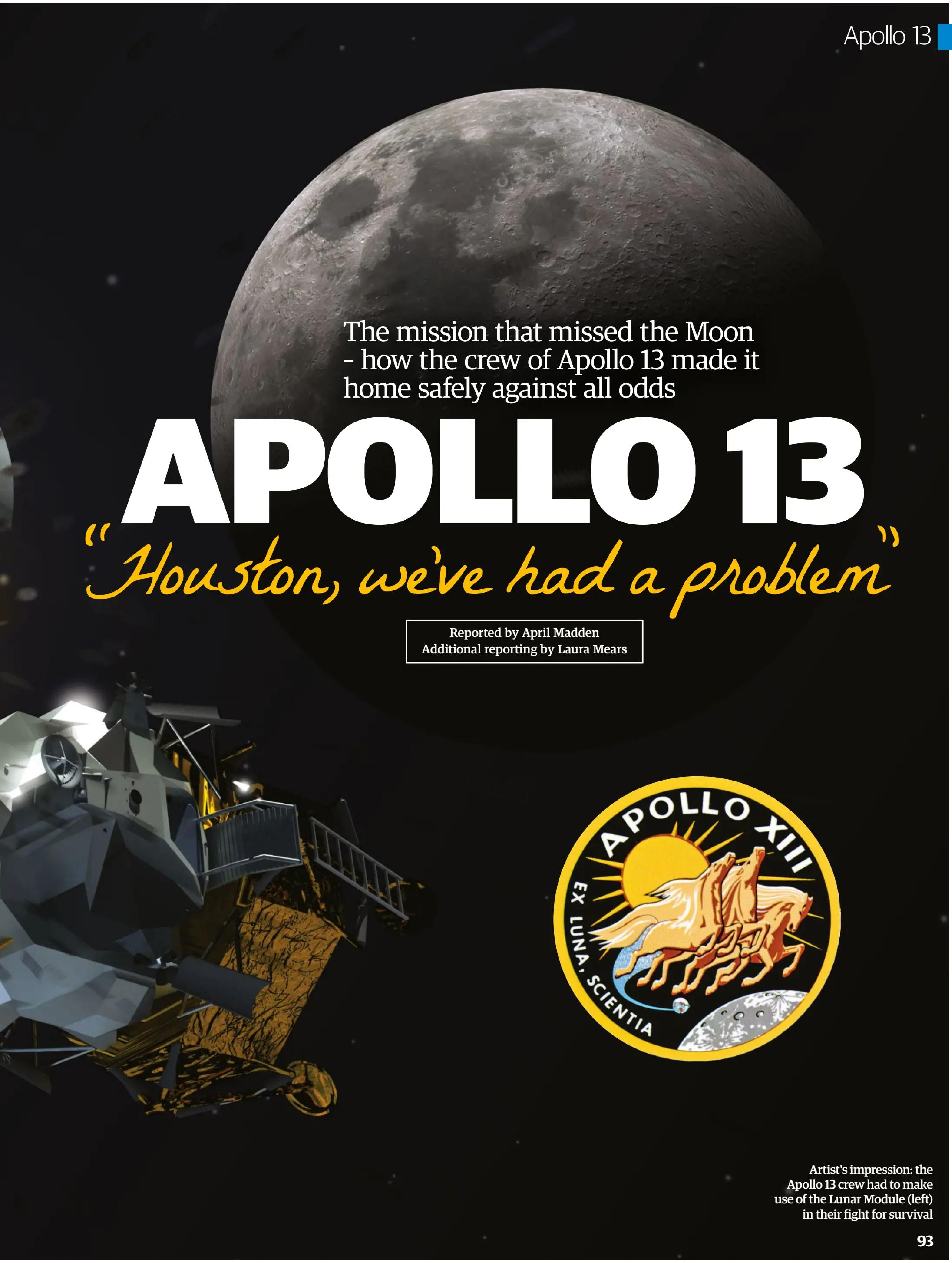
UNITED STATES

The mission that missed the Moon - how the crew of Apollo 13 made it home safely against all odds

APOLLO 13

"Houston, we've had a problem"

Reported by April Madden
Additional reporting by Laura Mears



Artist's impression: the Apollo 13 crew had to make use of the Lunar Module (left) in their fight for survival

© NASA; SpoonGraphics

After performing two successful Moon landings, NASA had pulled ahead of the Soviet Union as the undisputed leader in the Space Race. But a potentially fatal accident on its third lunar surface-bound mission was about to bring it back down to Earth.

Apollo 13 was surrounded with superstition from the start, the number 13 believed to be unlucky, but NASA wasn't going to let that get in the way of science. The public and the press, however, seemed more focused on the mission's designation than its aims, with many questioning why NASA even needed to revisit the Moon after the successes of Apollo 11 and 12. NASA knew these landings were more than just a novelty, so the Apollo program continued – for now – and Deke Slayton, director of Flight Crew Operations at the time, put forward his suggestion for the Apollo 13 crew.

Slayton's proposed line-up had Alan Shepard, one of the original Mercury Seven, as Commander, but management – concerned Shepard might be out of practice after surgery to correct his Ménière's disease, which had grounded him since 1963 – rejected the proposal. Not wanting to split up his crew, the entire Apollo 14 crew was brought forward to fly on Apollo 13 instead.

Previously the back-up crew for the historic Apollo 11, the crew was commanded by Jim Lovell, a NASA veteran who had flown across the Gemini and Apollo programmes, with Command Module (CM) pilot Ken Mattingly and Lunar Module (LM) pilot Fred Haise, both of whom hadn't yet travelled to space.

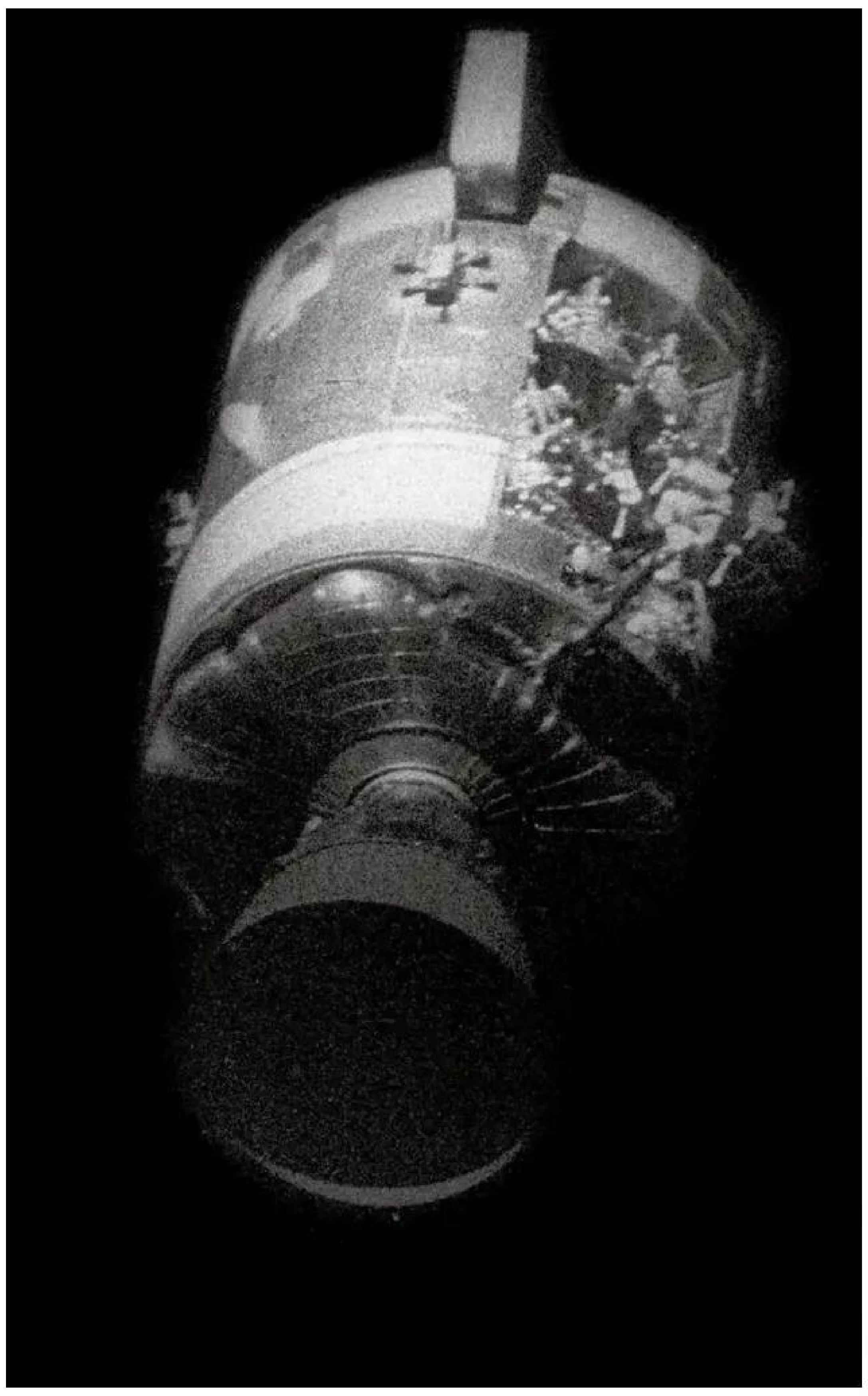
The crew trained rigorously in the months leading up to launch, going through figures and simulations to get them used to the confined workspace and testing their responses to the multitude of things that could go wrong in-flight. All of their training had prepared them for just about any eventuality, but soon things would start going wrong.

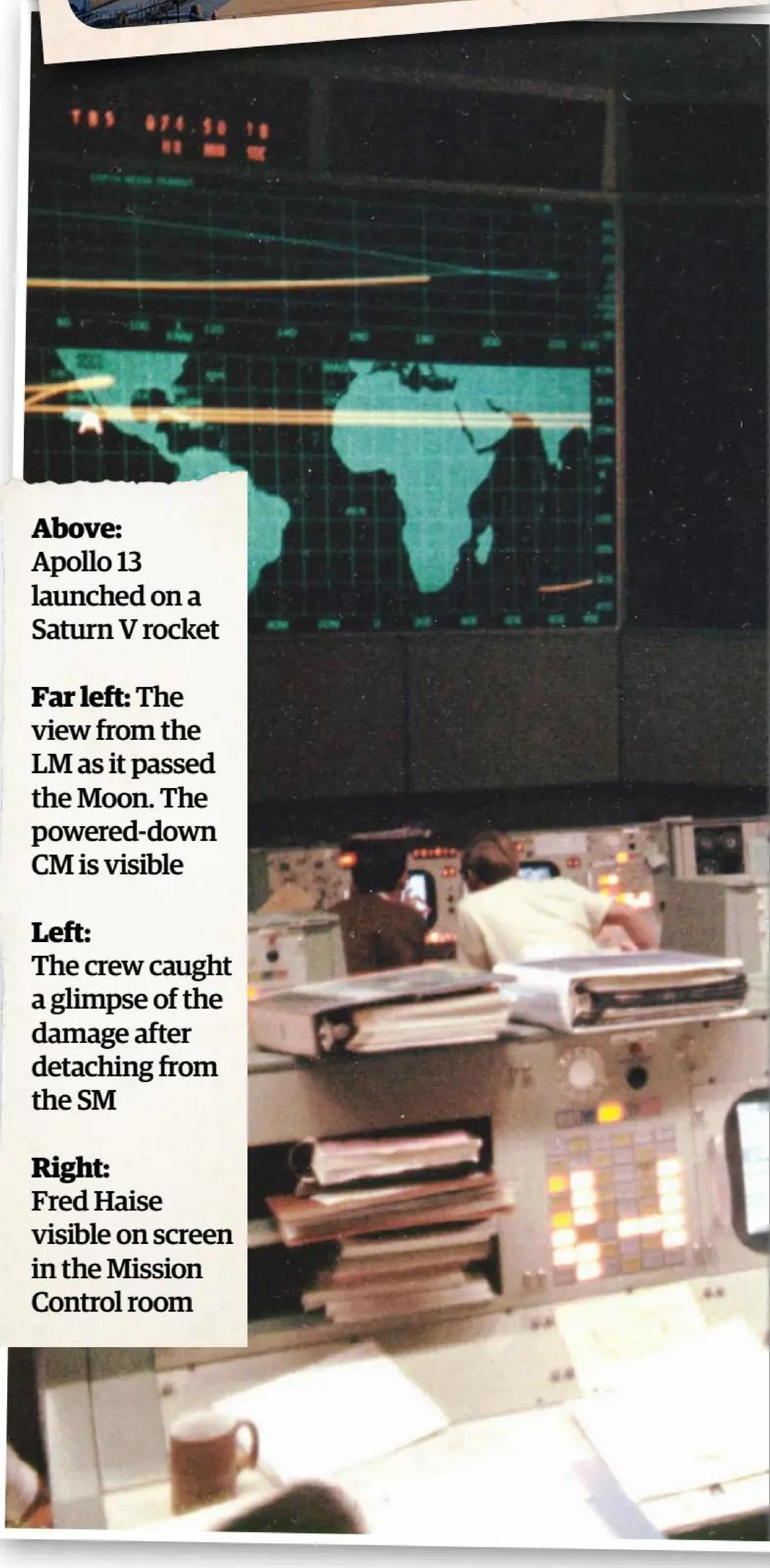
Just seven days before launch, the back-up LM pilot, Charlie Duke, contracted rubella, or German measles, from one of his children. Since the crew had been training in close proximity to their back-ups, this meant that everyone had been exposed, risking infection. A look through their medical histories showed that the only one who hadn't already had the disease was Mattingly, and the timeframe meant that he was at risk of showing symptoms while in control of the CM. The entire mission was jeopardised.

With less than a week to decide what to do, the pressure was on. Mattingly insisted he was good to fly, while the flight surgeon said the risk was too great. Switching to the back-up crew wasn't an option seeing as Duke was out of commission with illness, so NASA would have to go against protocol and place back-up CM pilot John 'Jack' Swigert on the mission, though Lovell fought all he could to keep his crew together before conceding. Three days of intense training followed to make sure the team could work as one, and the mission was kept on schedule for 11 April 1970.

Happy to proceed as scheduled with the last-minute crew changes, the day of the launch came.

> "Since the crew had been training in close proximity to their back-ups, this meant that everyone had been exposed"





Above: Apollo 13 launched on a Saturn V rocket

Far left: The view from the LM as it passed the Moon. The powered-down CM is visible

Left: The crew caught a glimpse of the damage after detaching from the SM

Right: Fred Haise visible on screen in the Mission Control room

The crew

U.S.S. IWO JIMA
ASTRONAUT
HAISE
APOLLO 13
U.S.S. IWO JIMA
ASTRONAUT
SWIGERT
APOLLO 13
U.S.S. IWO JIMA
ASTRONAUT
LOVELL
APOLLO 13
NASA

Right:
The crew of Apollo 13 aboard the USS Iwo Jima after recovery from the Command Module. From left to right: Lunar Module pilot Fred Haise, Commander James Lovell, and Command Module pilot John Swigert

The three men boarded the CM, nicknamed Odyssey, at the tip of a Saturn V rocket at the Kennedy Space Center in Florida. Here NASA was reminded again of waning interest in space exploration with a launch turnout of around 200,000 people - it was a crowd that paled in comparison to the 7 million who had come to see Apollo 11 lift off almost a year earlier.

The launch was completed at the scheduled time, the Saturn V rocket achieving orbit with just a minor problem when its second-stage inboard engine stopped firing prematurely due to the intense vibrations. Luckily their course was easily corrected by burning the four outboard engines and the third-stage engine a little longer, and the crew was seemingly safe, heading for the designated lunar landing site of the Fra Mauro highlands. After pulling away from the exhausted third stage and successfully docking Odyssey to the LM Aquarius, Lovell, Swigert and Haise settled in for the rest of their journey to the Moon.

But things weren't to go as planned. Approaching 56 hours into the mission and around 330,000 kilometres (205,000 miles) from home, the crew had just ended a live TV broadcast - though not many TV stations were interested enough to show

© NASA; SpoonGraphics

it. Noticing a slight drop in pressure, Houston flight controllers wanted to check the oxygen levels in the Service Module (SM), so they asked Swigert to perform a routine cryo stir on the tanks. This is where things went horribly wrong.

The crew heard a loud bang from outside and called down to Houston to report. Both the crew and the ground team noticed that the oxygen tanks and fuel cells were showing alarming readings, with oxygen tank two completely depleted and tank one falling at a steady rate. Several people at Mission Control assumed this was a fault with instrumentation, as no simulation had ever shown such equipment failure, but Lovell reported he could see a gas leaking out of the SM, confirming their readings were worryingly correct.

They would later discover that a current overload in an oxygen tank during routine testing shorted out the heater switch and had fused the circuit breaker shut, turning the tank into a bomb. A bomb that had been set off when Swigert had started the stir, and blown a 3.9-metre (13-foot) panel off the SM. With power and oxygen failing fast, Apollo 13's mission was no longer a lunar landing, but returning home.

Mission Control had to think quickly, calling in staff in the middle of the night and running emergency simulations. Debate raged on if the crew should be instructed to manoeuvre towards Earth straight away to return quicker, but Gene Kranz and others argued that propulsion couldn't be relied on at current power levels.

It was decided that the remaining fuel cell for the CM needed to be preserved for re-entry, since this was impossible in the LM. The crew would need to power down the CM and evacuate to the Aquarius, which could be used as a lifeboat since it had its own life-support system. This, however, presented problems: the LM was only designed for two astronauts to visit the

AS13-59-8484

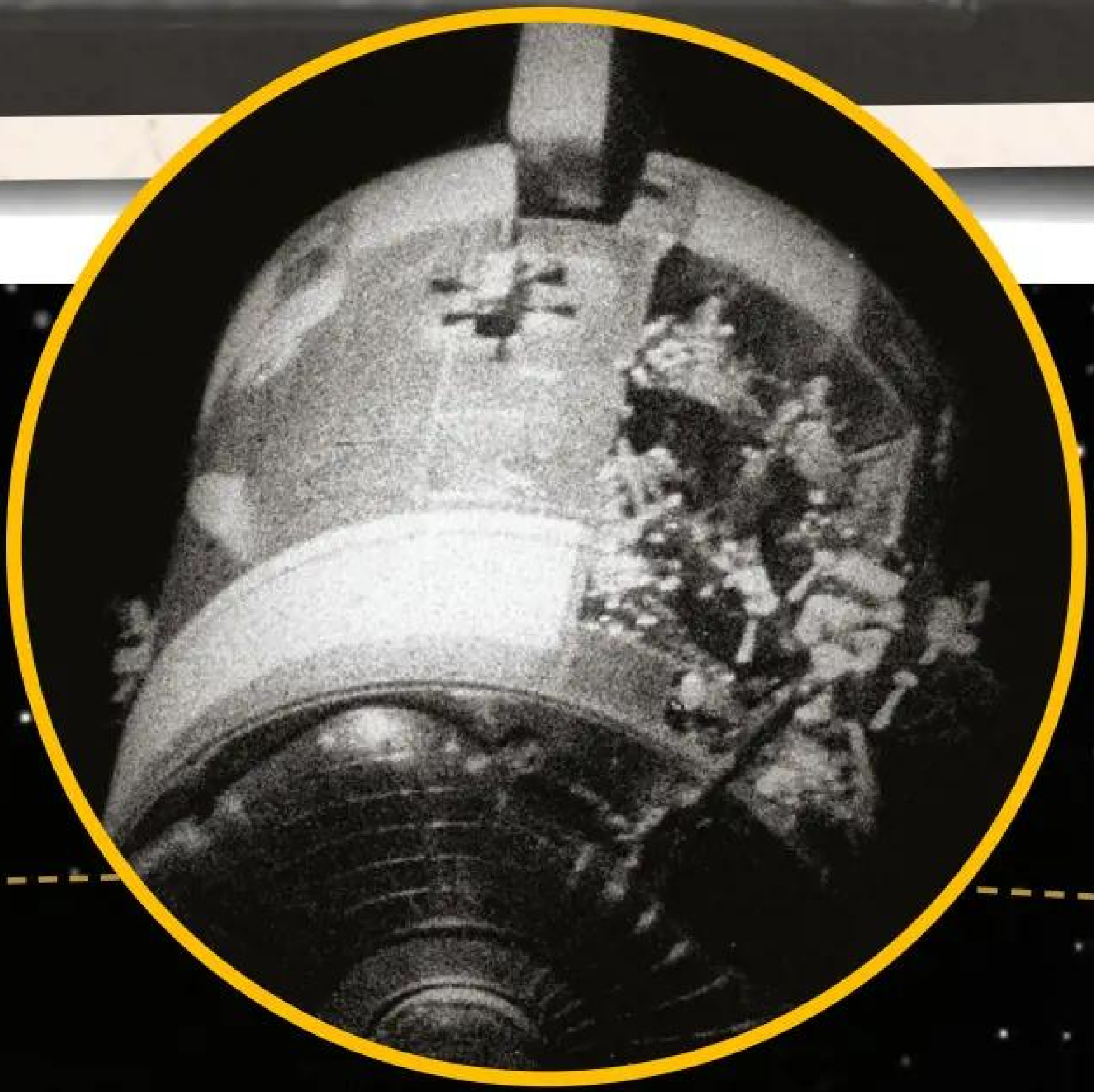
Mission timeline

8. Return home

Time: 142:40:45
Apollo 13 re-entered the atmosphere almost four days after the disastrous explosion, carrying the exhausted crew to a gentle ocean splashdown.

7. Assessing the damage

Time: 138:01:48
The damaged SM was released into space, and the crew were able to view the extent of the explosion for the first time.



Powering on

Time: 140:10:00
The CM was brought back online shortly before the crew reached Earth.

> "Mission control held its breath as the crew dropped through the atmosphere"

1. Lift-off

Time: 00:00:00
Apollo 13 was the third manned mission to the lunar surface, and the crew planned to explore the Fra Mauro region on the near-side of the Moon.

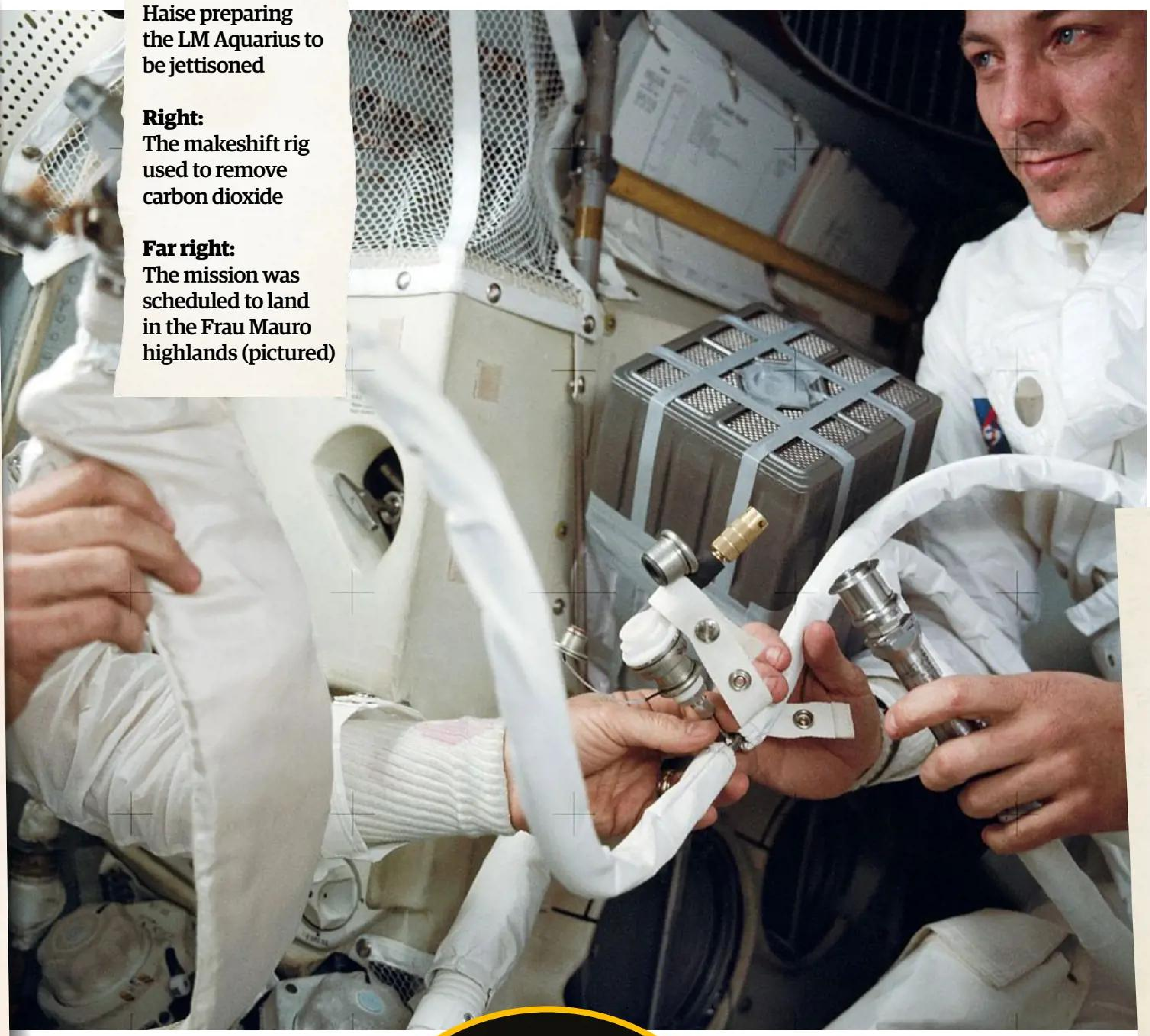
2. Television transmission

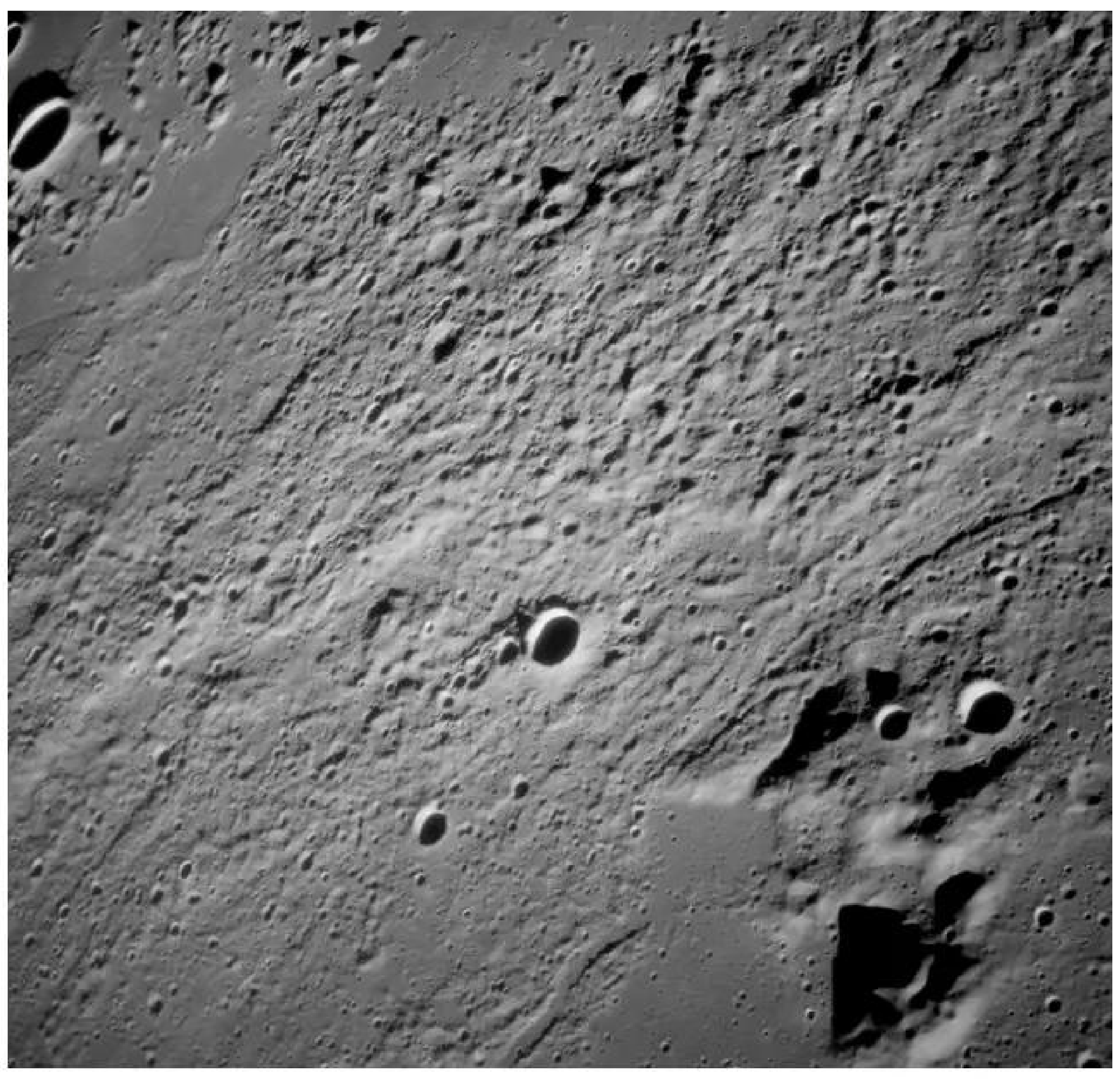
Time: 55:14:00
Shortly before the explosion, the crew took part in a live television broadcast back to Earth, showing viewers what life was like inside the module.

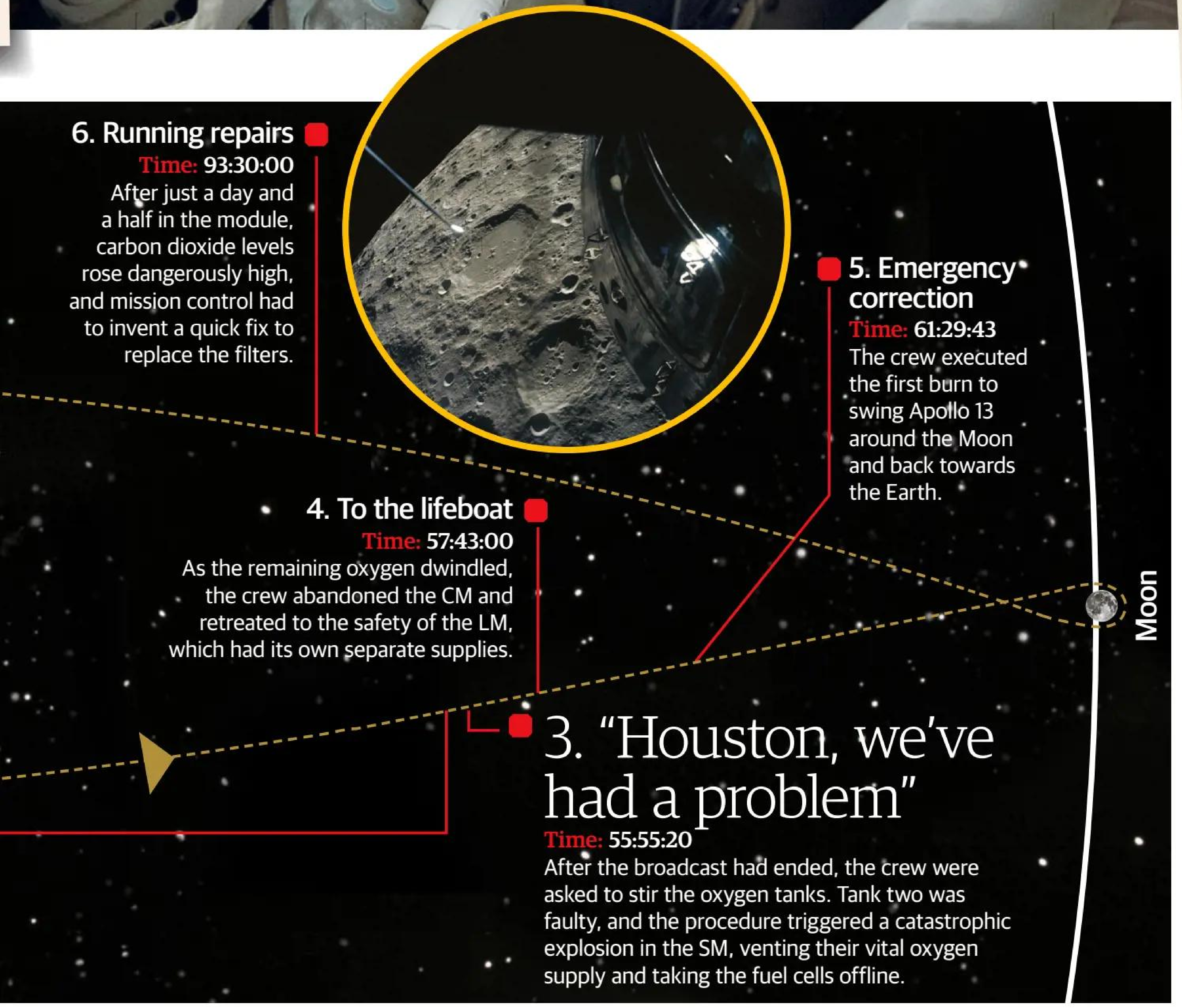
Left:
Haise preparing the LM Aquarius to be jettisoned

Right:
The makeshift rig used to remove carbon dioxide

Far right:
The mission was scheduled to land in the Frau Mauro highlands (pictured)







6. Running repairs
Time: 93:30:00
After just a day and a half in the module, carbon dioxide levels rose dangerously high, and mission control had to invent a quick fix to replace the filters.

5. Emergency correction
Time: 61:29:43
The crew executed the first burn to swing Apollo 13 around the Moon and back towards the Earth.

4. To the lifeboat
Time: 57:43:00
As the remaining oxygen dwindled, the crew abandoned the CM and retreated to the safety of the LM, which had its own separate supplies.

3. "Houston, we've had a problem"

Time: 55:55:20
After the broadcast had ended, the crew were asked to stir the oxygen tanks. Tank two was faulty, and the procedure triggered a catastrophic explosion in the SM, venting their vital oxygen supply and taking the fuel cells offline.

NASA's Apollo 13 report

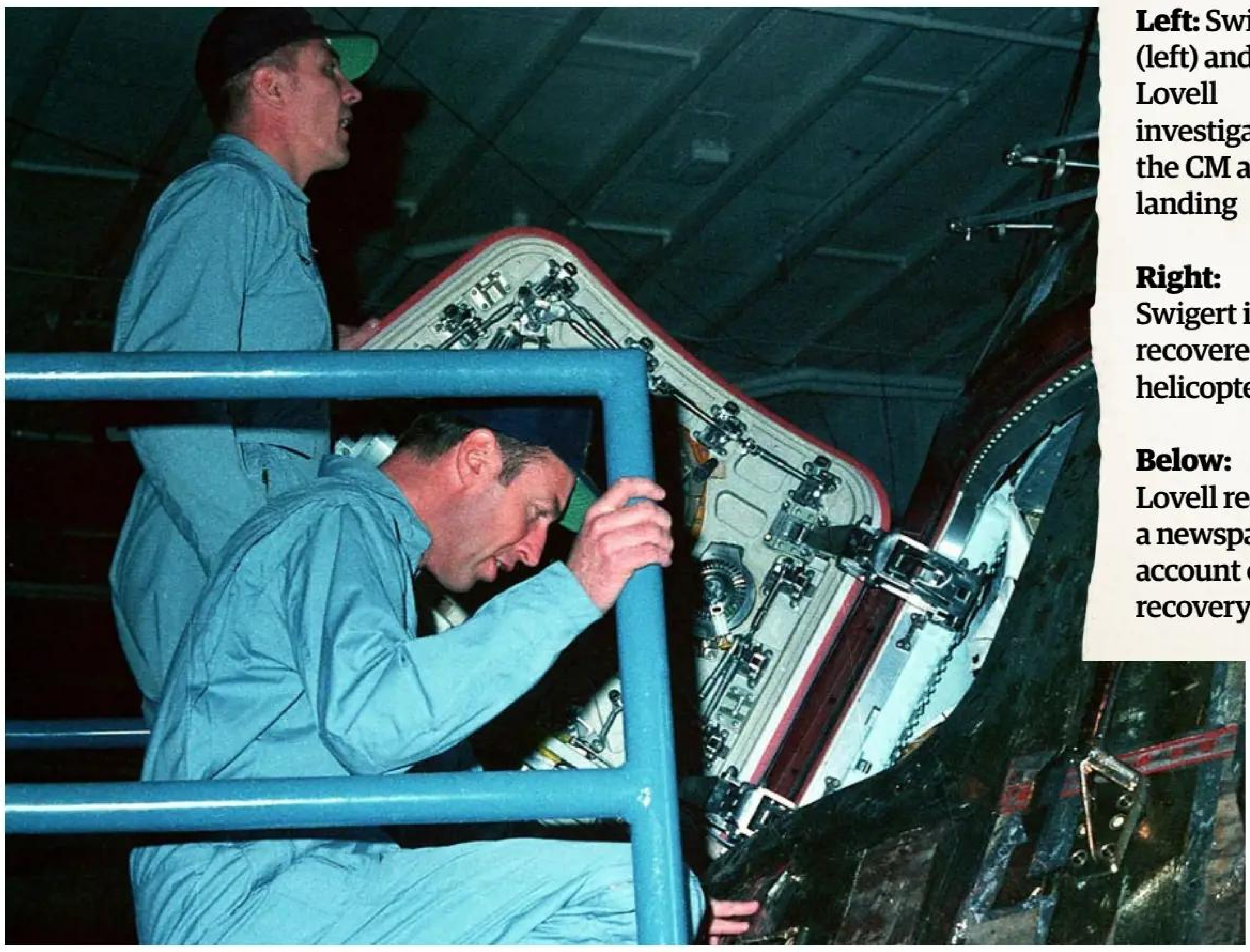
"The Apollo 13 accident, which aborted man's third mission to explore the surface of the Moon, is a harsh reminder of the immense difficulty of this undertaking.

The total Apollo system of ground complexes, launch vehicle, and spacecraft constitutes the most ambitious and demanding engineering development ever undertaken by man. For these missions to succeed, both men and equipment must perform to near perfection. That this system has already resulted in two successful lunar surface explorations is a tribute to those men and women who conceived, designed, built, and flew it.

Perfection is not only difficult to achieve, but difficult to maintain. The imperfection in Apollo 13 constituted a near disaster, averted only by the outstanding performance on the part of the crew and the ground control team which supported them.

The Apollo 13 Review Board was charged with the responsibilities of reviewing the circumstances surrounding the accident, of establishing the probable causes of the accident, of assessing the effectiveness of flight recovery actions, of reporting these findings, and of developing recommendations for corrective or other actions. The Board has made every effort to carry out its assignment in a thorough, objective, and impartial manner. In doing so, the Board made effective use of the failure analyses and corrective action studies carried out by the Manned Spacecraft Center and was very impressed with the dedication and objectivity of this effort.

The Board feels that the nature of the Apollo 13 equipment failure holds important lessons which, when applied to future missions, will contribute to the safety and effectiveness of manned space flight."



Left: Swigert (left) and Lovell investigate the CM after landing

Right: Swigert is recovered by helicopter

Below: Lovell reads a newspaper account of the recovery

“The oxygen tanks and fuel cells were showing alarming readings”

Moon for around 20 hours, whereas their trip home would be four or five days. Also, engineers weren’t sure if the SM would power back on after being inactive for so long. Still, there wasn’t much choice. The crew was instructed to power up the LM and transfer guidance parameters from the CM before powering it down. It usually took three to five hours to power up a LM – they had just 90 minutes.

The next hurdle was aligning the LM to the correct attitude, Swigert having to read out coordinates so that Lovell and Haise could manually relay this to the LM. As soon as the situation was stabilised, Swigert joined them in the LM and the CM powered down completely. Everyone on the ground was hard at work performing simulations and calculations to work out how the crew could get home. Before the explosion the spacecraft had departed its free-return trajectory – a method of using the Moon’s gravity to return to Earth – in preparation for the lunar landing. This meant that the craft would need to realign itself, as it didn’t have the power to make it back without this assist. But this was a problem, as the propulsion system on the SM couldn’t be used. The crew would have to attempt trajectory correction using only the thrusters on the LM, which were designed for descent to the Moon.

Calculations from Mission Control were passed to the crew, who successfully re-entered free return with expert piloting. However, their problems weren’t over. Though they had plenty of oxygen, it was realised that the LM was still using a lot of power, and didn’t have enough water on board to cool all the electrical equipment. The crew was instructed to turn off everything non-essential, leaving them with a small light, a fan and a radio to keep in touch with Houston. They also had to ration their water to one-fifth of normal consumption, risking dehydration. Back on Earth there was renewed interest in the mission, with disaster drawing the public eye and the whole world wondering if they would make it. Many countries including, surprisingly, the USSR, offered any help they could to get the men home.

As the craft drifted 254 kilometres (157 miles) beyond the far side of the Moon, another manoeuvre was planned to speed up the journey to be performed two hours after pericynthion, the closest approach to the Moon. It was also debated whether the SM should be jettisoned to increase speed further, but some argued this could expose the CM’s heat shield to the freezing cold of space for too long, risking it breaking on re-entry. This would also involve using all remaining fuel, meaning no other course corrections could be performed later. NASA chose the safer option of a four-minute burn, which would shave off 12 hours of flight and put the craft on target with the Pacific Ocean.

Almost 24 hours after the explosion, the crew completed another successful burn. However, now carbon dioxide levels were rising. The scrubbing system aboard the LM wasn’t designed to filter air for three, and calculations saw that the lithium hydroxide canisters that removed the CO_2 would not support the crew until return. The CM had its own supply of canisters, but because of a different design these were incompatible. It was up to Houston to find a makeshift filtration method using only items on board Apollo 13. Within 35 hours of testing they had a fix utilising spacesuit hoses, plastic bags and duct tape. The next challenge was directing the astronauts how to copy their instructions, as if assembled incorrectly there was no hope of return.

With the filters safely in place and the crew maintaining a fine balance between power use and heat so that the CM wouldn’t freeze, concerns grew about the trajectory once more. Swigert

Honolulu Star-Bulletin
Nixon to Greet Them Here
Astronauts Safe
Nixon Due Here Tomorrow

U.S.S. IWO JIMA
ASTRONAUT
HAISE
APOLLO 13
SEAL OF THE PRESIDENT OF THE UNITED STATES

© NASA

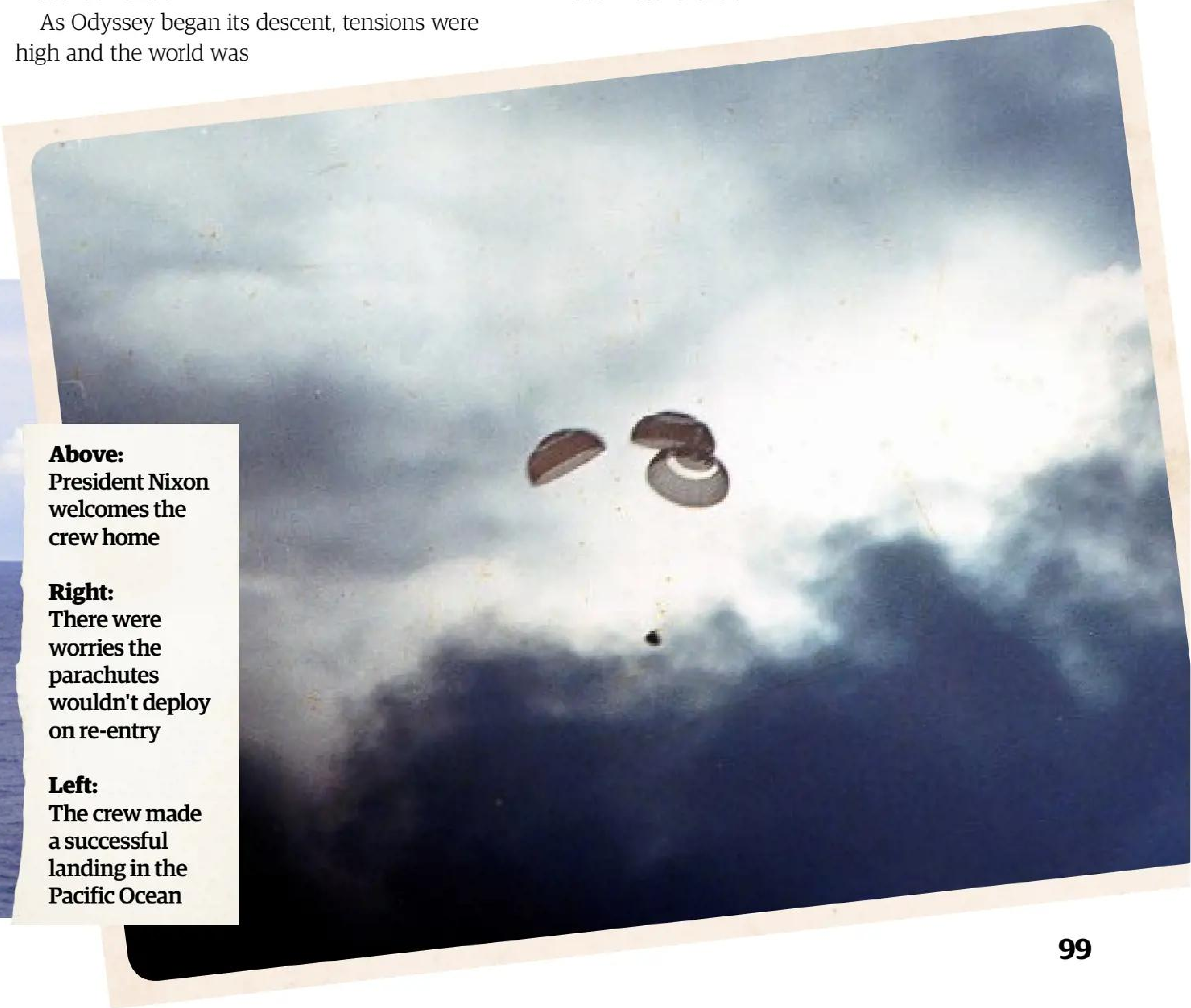
was convinced they were coming in too shallow, meaning they would bounce off the atmosphere and be lost to space. Another manoeuvre was planned to correct this, but the three pilots would have to use the Sun and Earth's terminator as a guide – the guidance systems would use up too much valuable power. Exhausted and dehydrated, the crew pulled it off, but the next problem was whether the CM would even power up. Luckily, during Apollo 10 a procedure had been simulated where the LM could charge the CM, though this involved manipulating several circuit breakers in order to backflow power.

On course and with power rerouted, things were looking up. However, there were still fears that the explosion may have damaged the heat shield on the SM, which would cause it to burn up on re-entry, or that the long journey may have frozen its parachutes closed. With just hours to go, the crew moved back into the CM with just enough power for re-entry. Ground control went over final procedures, and the crew prepared for the worst.

Next was to jettison the damaged SM while using the LM thrusters to move a safe distance from it. This was the first time the crew saw the extent of the explosion, relaying the damage down to the ground. The LM jettison was next, and a special last-minute procedure had been designed to keep distance by pressurising the connecting tunnel before release. Calculations were a success, and the crew bid farewell to Aquarius, the reason they had made it this far.

As Odyssey began its descent, tensions were high and the world was watching. Ionised air around the craft upon re-entry meant a total communications blackout, and for over four minutes NASA had no contact, fearing the shields or parachutes could still fail. After a longer-than-expected blackout, the crew finally made contact. They had made it home, splashing down in the Pacific Ocean to be picked up by USS Iwo Jima.

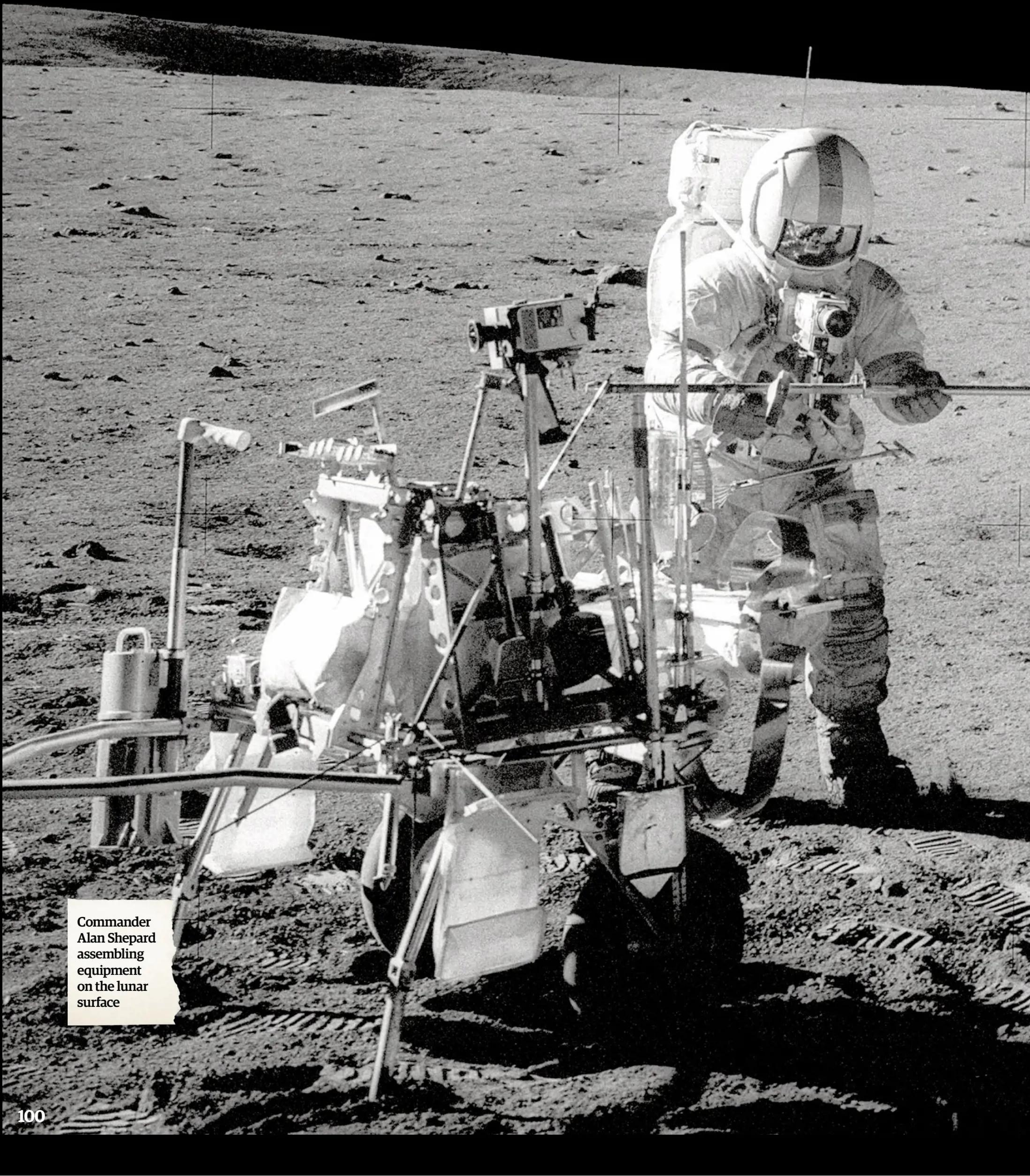
The mission was dubbed a 'successful failure', proving NASA could work well in a crisis. However, without the combined efforts of both the crew and the ground team, it's likely the mission would have been lost forever.



Above: President Nixon welcomes the crew home

Right: There were worries the parachutes wouldn't deploy on re-entry

Left: The crew made a successful landing in the Pacific Ocean



Commander Alan Shepard assembling equipment on the lunar surface

After Apollo 13 narrowly avoided disaster, a rookie crew and a famous golf ball helped put NASA back on track

APOLLO 14

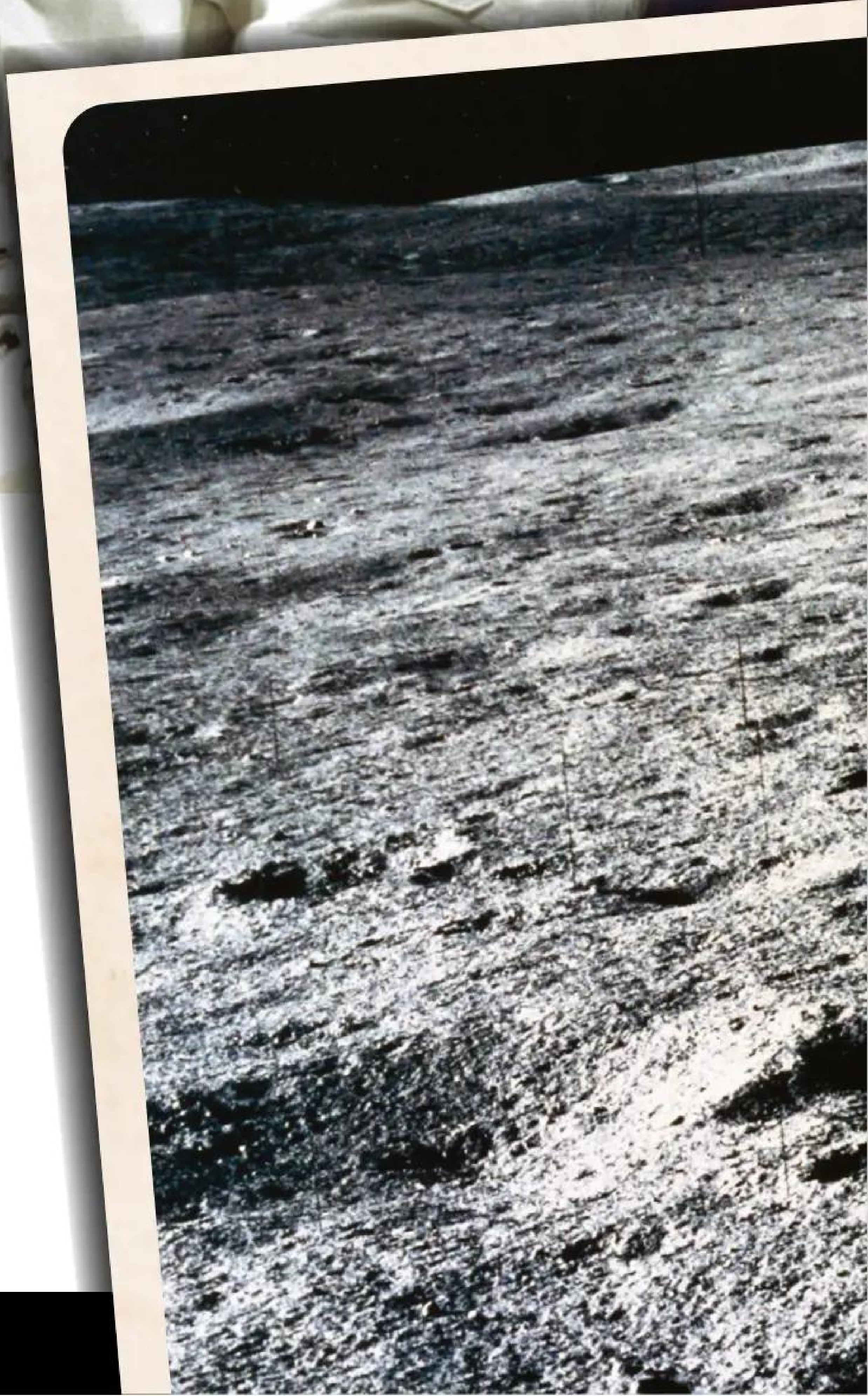
The 'Rookie' Mission

Reported by Elizabeth Howell

© NASA

APOLLO 14
Shepard
Roo
SHEPARD
ROOSA
NASA

Main:
The Apollo 14 crew, from left to right: Command Module pilot Stuart Roosa, Commander Alan Shepard, and Lunar Module pilot Ed Mitchell



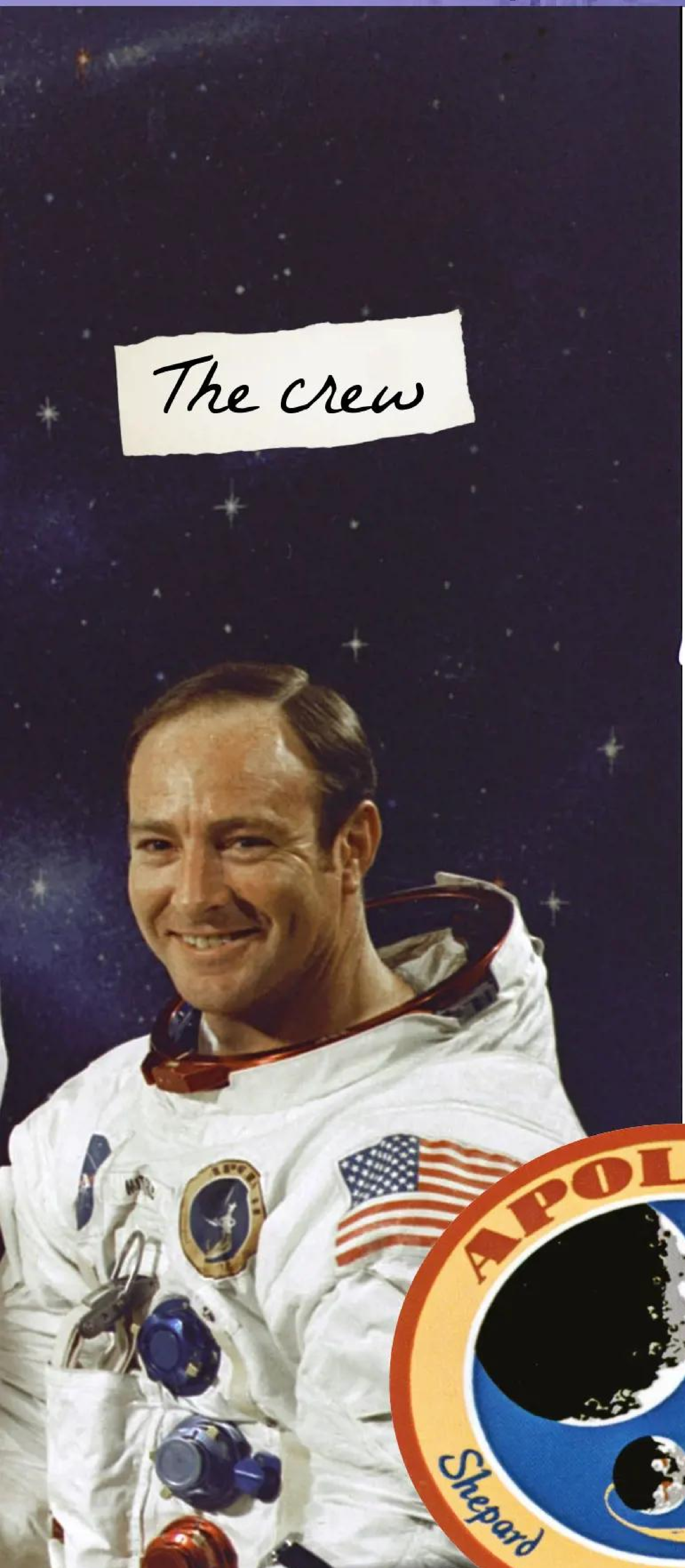
Apollo 14 was the third human mission to land on the Moon, and the first one since the Apollo 13 mission that experienced a dangerous explosion in space before the crew was returned safely to Earth. NASA made changes to the Apollo spacecraft design before Apollo 14 lifted off on 31 January 1971. Today, many people remember this mission as the one where an astronaut hit golf balls, but the crew also had other adventures. The team searched for evidence of an asteroid that carved a large crater in the Moon and fought glitches and false alarms as they made their way to the Fra Mauro highlands.

Their colleagues at NASA good-naturedly referred to the Apollo 14 crew as "the three rookies," because the team had only a few minutes of accumulated space experience among them.

Astronaut and Commander Alan Shepard was selected among the first group of American astronauts in 1959. He was the first American in space, making a 15-minute-and-28-second suborbital hop in 1961 aboard Freedom 7. NASA assigned him to the first Gemini mission, but Shepard developed symptoms of Ménière's disease, a disorder of the middle ear, and had to stop flying on his doctor's orders. In 1968, Shepard underwent risky surgery to alleviate his symptoms; the surgery was a success, and he was reassigned to flight status.

Lunar Module pilot Edgar Mitchell, selected as an astronaut in 1966, was one of the few astronauts

The crew



at the time who had a doctorate. In the US Navy, he not only flew planes, but also gave advanced mathematics and navigational lessons to aviators who were astronaut candidates. After five years at NASA, Mitchell had received accolades from his peers for his knowledge of the lunar landing module, which was likely factored in to NASA's decision to put him on Apollo 14, which was his only space mission.

Stuart Roosa, a former Air Force fighter pilot, joined NASA in 1966 and was the Command Module pilot for Apollo 14. He served as CapCom (the person who communicates with astronauts during a mission) for the Apollo 9 mission, and impressed NASA with his ability to help the astronauts after crew member Rusty Schweickart fell ill. Roosa became the first Apollo astronaut assigned to a flight crew without having completed a backup assignment first. Apollo 14 was Roosa's only space mission.

The three men were initially scheduled to fly on Apollo 13, but they agreed to take on a later mission so they could receive extra training. This was especially useful for Shepard, who had just resumed active duty in the Navy.

A launch glitch

Apollo 14 launched smoothly, aiming for the Fra Mauro highlands, a hilly region of the Moon that Apollo 13 had hoped to reach. However, the Apollo 14 astronauts ran into trouble as they were preparing to leave Earth orbit. One of their required tasks was to dock the Command Module Kitty Hawk against the lunar lander (or Lunar Module) Antares to fly the two craft to the Moon, but the docking latches didn't work. After a suggestion from Mission Control to fire Kitty Hawk's thrusters hard and push the ships together, the latches were finally locked successfully.

Landing on the Moon didn't come easily for the astronauts, either. Antares' radar wasn't working until the last minute. The radar on Antares needed to work to satisfy NASA's rules for landing on the Moon; otherwise, the mission would be aborted. Once the radar was functioning properly, Shepard made an on-target landing.

Shepard's first words when he walked on the Moon's surface were, "It's been a long way, but we're here." Mitchell scrambled down after him and the two immediately got to work setting up experiments on the lunar surface.

Above: Commander Alan Shepard plants the US flag after landing on the lunar surface

Left: As well as Shepard's golf swings, Ed Mitchell (pictured) threw a lunar scoop handle as if it were a javelin

© NASA; Getty Images

For the first time, the crew had a small handcart to help them carry rocks and equipment around the Moon's surface. Sitting 111 kilometres (69 miles) above Mitchell and Shepard, Roosa took pictures of the Moon as he worked through his assigned list of scientific experiments.

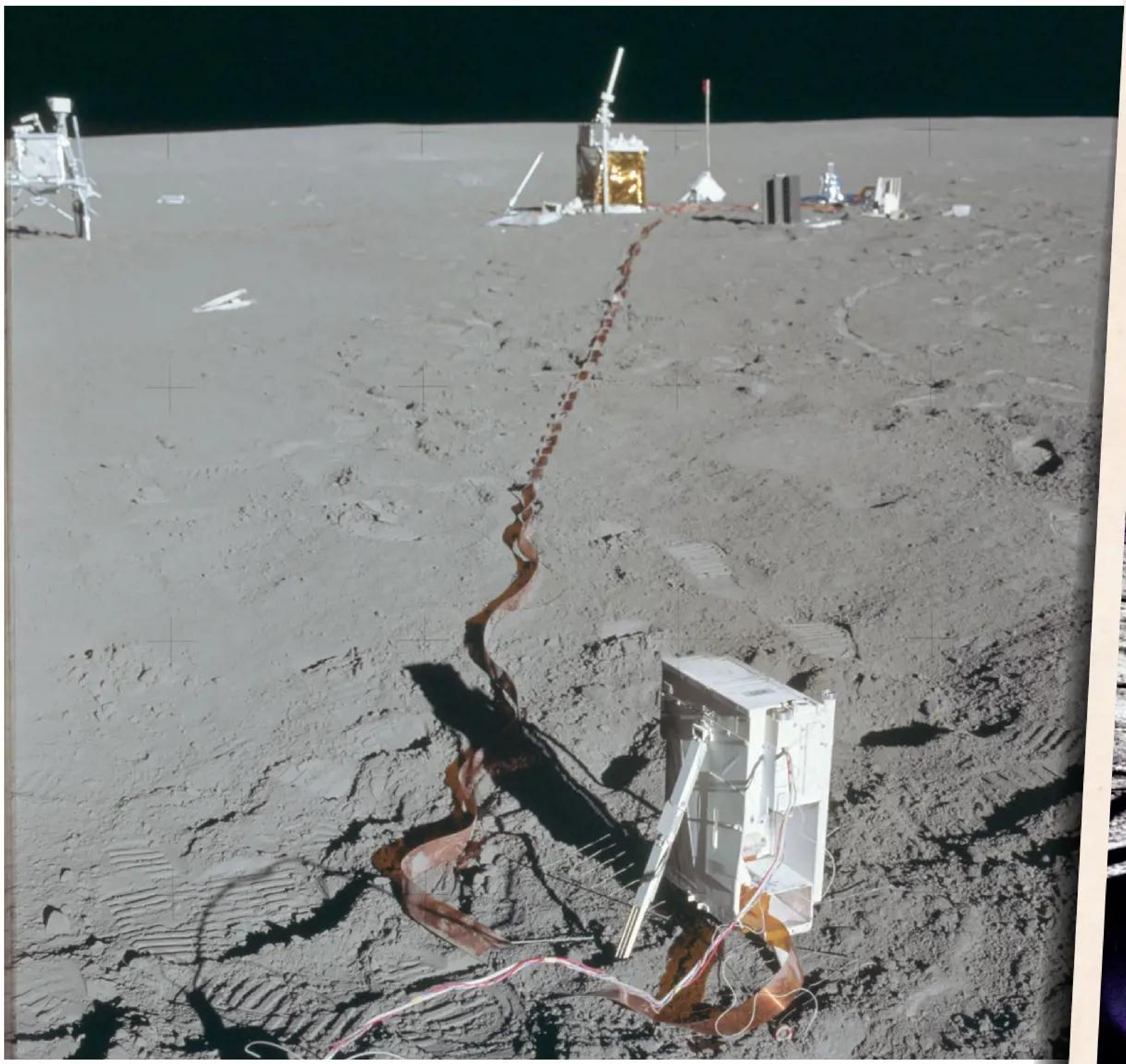
On 6 February 1971, Apollo 14 astronaut Alan Shepard became the first person to play golf on the Moon. He smuggled a makeshift golf club head onto the spacecraft inside a sock. The first ball he hit veered into a nearby crater, but with a solid second swing, the next ball soared for "miles and miles and miles" in the Moon's microgravity.

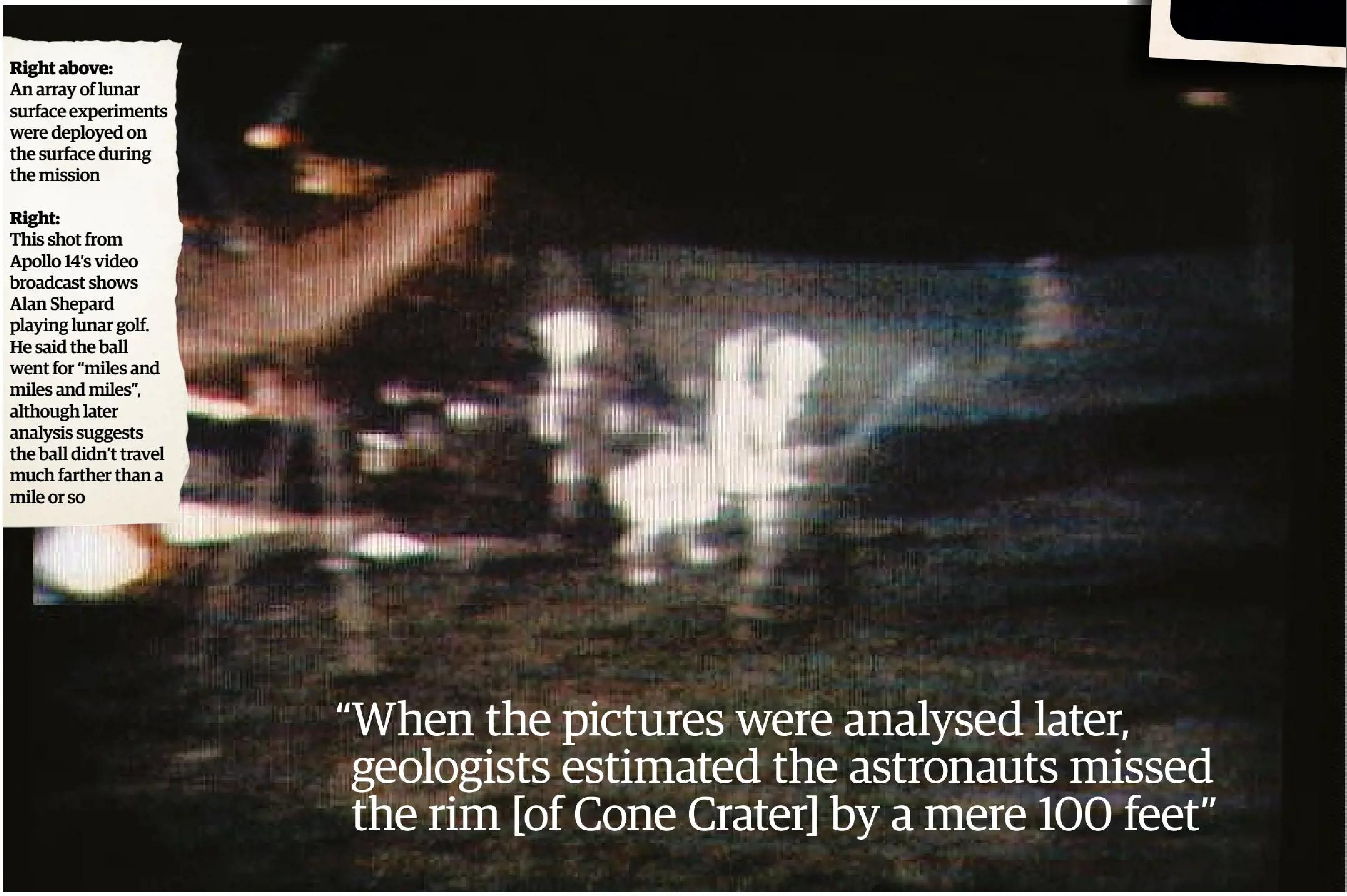
Hitting golf balls

Apollo 14's prime geologic target was Cone Crater. The crew planned to climb the slope, reach the rim – which was 91 metres (300 feet) above the landing site – and then look for rocks that could have flown up from the Moon's bedrock after a meteor smashed into the surface millions of years earlier.

The astronauts found the climb harder than expected. Rocks littering the slope forced them to carry the cart, and the steep climb meant they had to rest often. Mission Control asked the astronauts for updates on how close they were to the rim; the astronauts guessed they were nearby, but it was hard to say for sure.

Eventually, Shepard and Mitchell ran out of time and were forced to move on. When the pictures





Right above: An array of lunar surface experiments were deployed on the surface during the mission

Right: This shot from Apollo 14's video broadcast shows Alan Shepard playing lunar golf. He said the ball went for "miles and miles and miles", although later analysis suggests the ball didn't travel much farther than a mile or so

> "When the pictures were analysed later, geologists estimated the astronauts missed the rim [of Cone Crater] by a mere 100 feet"

Left: The Lunar Module Antares reflects a jewel-like flare from the bright sunlight

Right: These second-generation Moon trees were planted in 2009 on the 40th anniversary of the Apollo 11 Moon landing and in celebration of Earth Day

were analysed later, geologists estimated the astronauts missed the rim by a mere 30 metres (100 feet).

Before leaving the Moon, Shepard performed an entertaining stunt for the television audience watching from home. He brought a 6-iron with him as well as a "little white pellet that's familiar to millions of Americans", he said to the viewers back on Earth. In front of the camera, he hit one golf ball into a nearby crater and a second one that went "miles and miles and miles", according to Shepard. But in reality, neither golf ball could have travelled more than a mile.

Apollo 14 legacy

Apollo 14 splashed down in the Pacific Ocean on 9 February, and NASA began its next set of lunar missions - all of which featured lunar rovers. NASA flew three more crewed missions to the Moon, with the last one leaving in December 1972.

Kitty Hawk's current location is the Kennedy Space Center Visitor's Center near Titusville, Florida, while Antares' upper stage crashed on to the Moon on 7 February 1971.

500 seeds were taken aboard Apollo 14, and orbited the Moon in the Command Module. Upon the mission's return, the seeds were sent to the US Forest Service to attempt to grow them - over 400 successfully germinated. Many first and second-generation 'Moon trees' have been planted across the US, and some internationally. One such tree, a Loblolly pine, was planted at the White House.

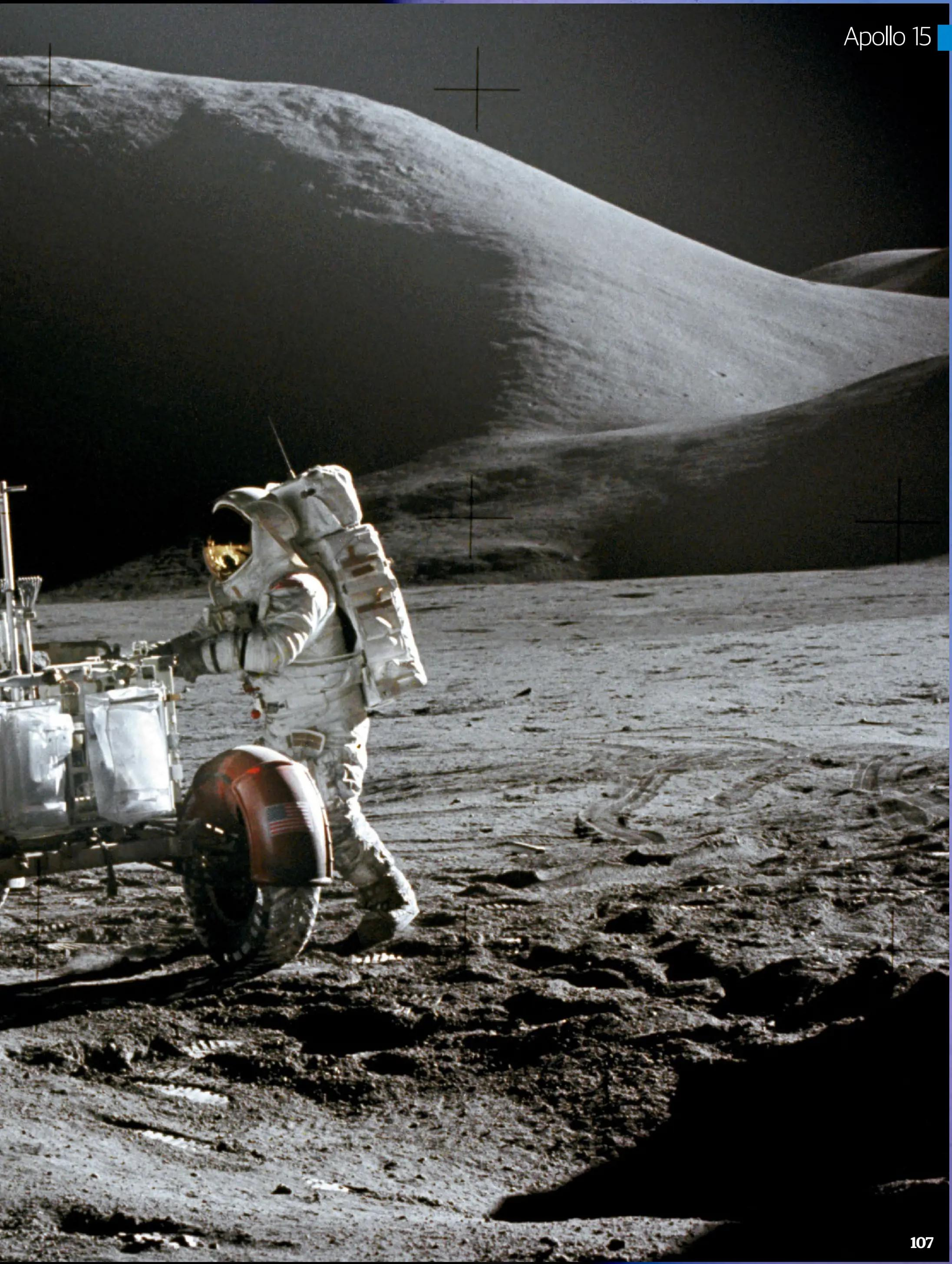
© NASA; Getty Images

The introduction of a rover enabled astronauts to explore more of the lunar surface than ever before

APOLLO 15

The Moon buggy's debut

Reported by Elizabeth Howell



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Apollo 15, which launched on 26 July 1971, marked the beginning of NASA's most challenging crewed missions to the Moon. This mission featured the longest stay yet on the lunar surface, three moonwalks and the first use of a "Moon buggy," or lunar rover. Only two more crewed missions followed after Apollo 15: Apollo 16 and Apollo 17.

In the training for Apollo 15, the mission's three astronauts put an emphasis on geological work. They spent many hours in the field learning how to identify different types of rocks and formations. The crew, all former US Air Force pilots, had trained together in the past, serving as backups for the Apollo 12 mission.

Commander Dave Scott had two spaceflight missions under his belt. He was the Command Module pilot on Apollo 9, which featured the first Apollo docking in space. He also flew on an eventful Gemini mission in 1966. Gemini 8 had a malfunctioning thruster that spun the spacecraft around so fast that the astronauts almost lost consciousness; crewmate Neil Armstrong managed to pull Gemini 8 out of the lurch by activating the re-entry system.

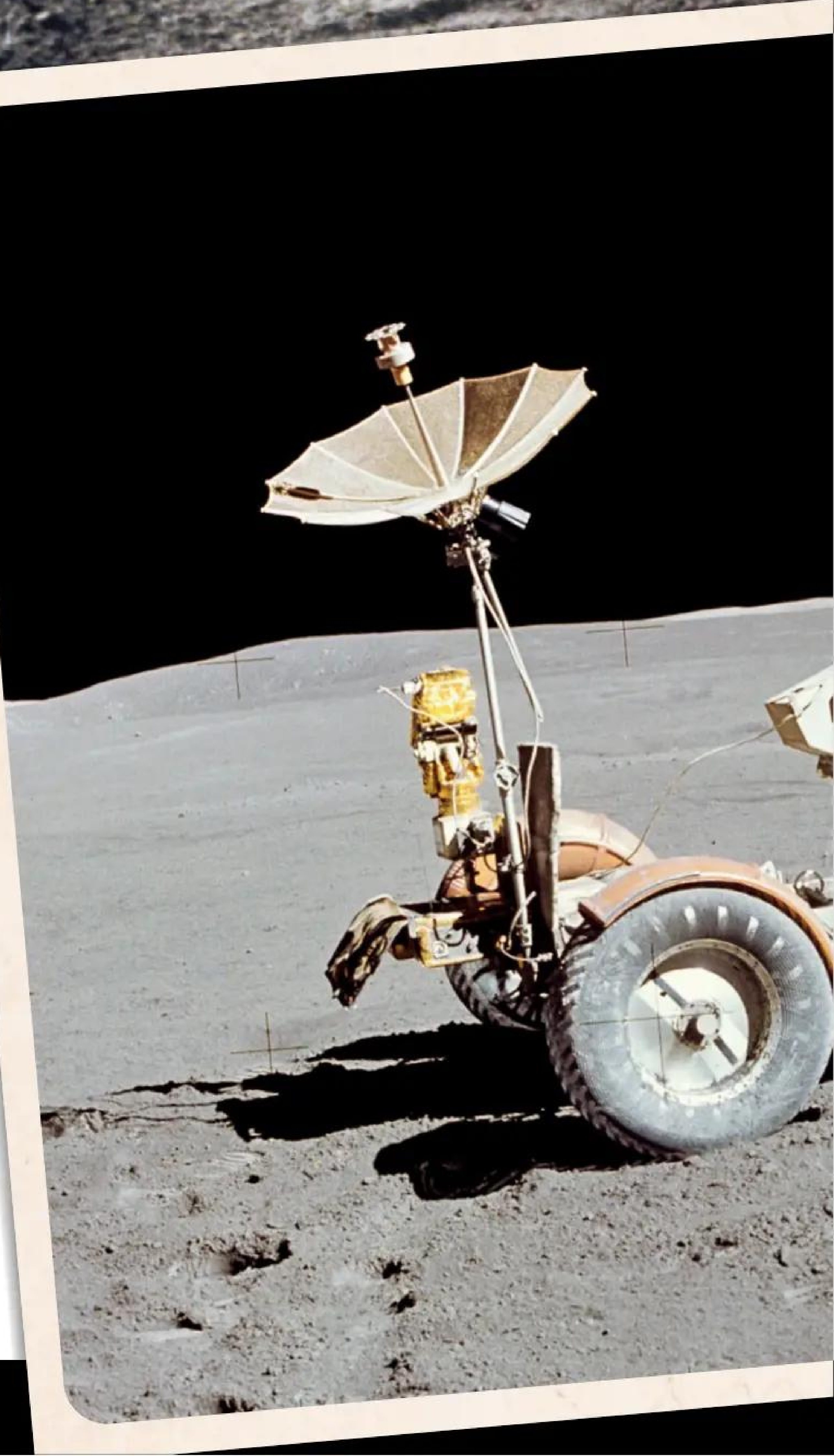
Jim Irwin was the Lunar Module pilot for Apollo 15, and Al Worden was the Command Module pilot. Previous to NASA, Irwin was an experimental test pilot and F-12 pilot with the Air Force, while Worden was an instructor at the Aerospace Research Pilot School with the US Air Force. Apollo 15 was the only spaceflight for each of these astronauts.

A rocky test drive

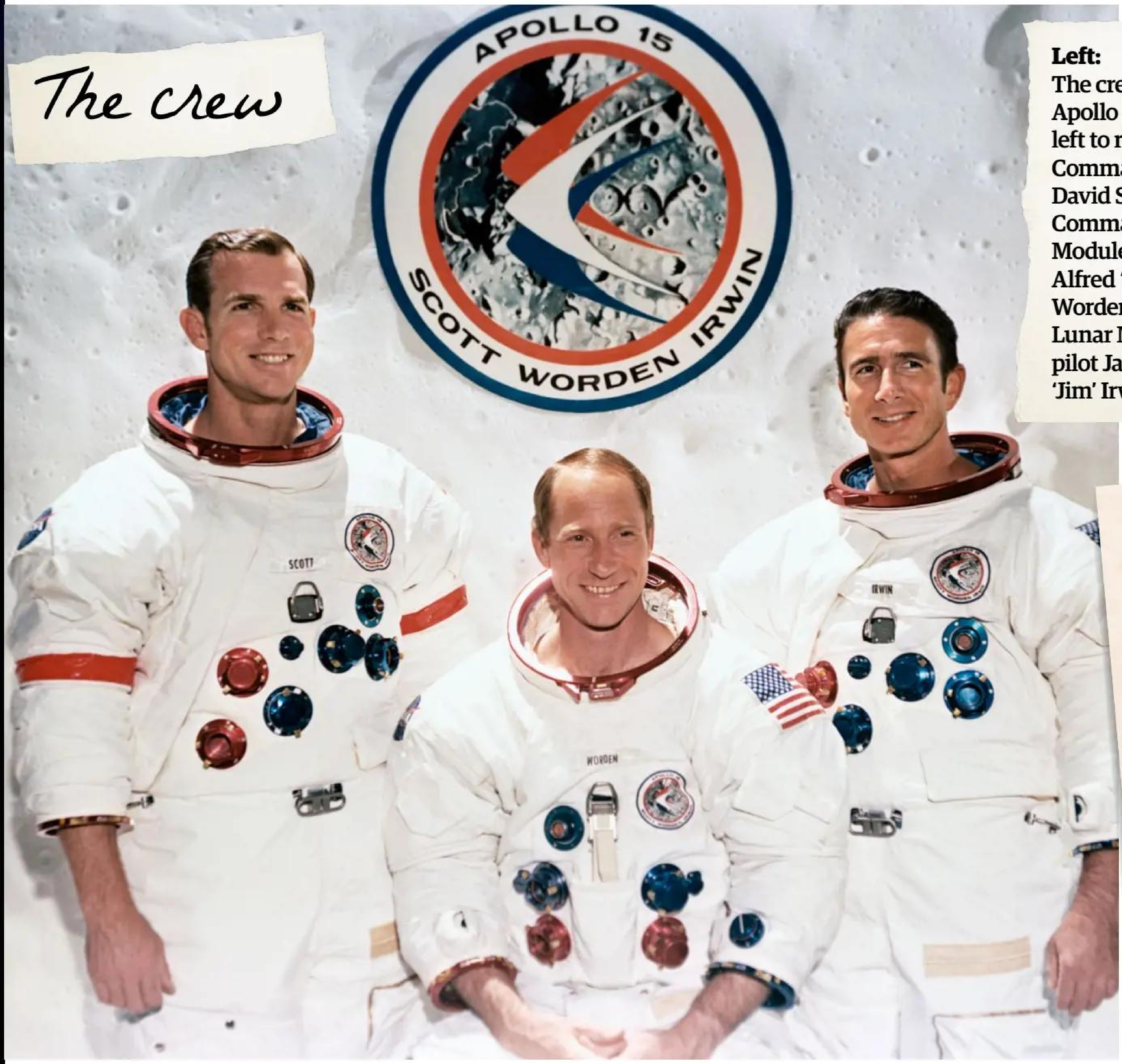
After several missions of choosing progressively challenging landing sites, NASA wanted to aim even higher for Apollo 15. NASA described the site it came up with for the landing – Hadley Rille, on the edge of Mare Imbrium – as "spectacularly beautiful." More importantly, it was a treasure trove of geologic treasure, including mountains, craters and Hadley – a large canyon.

Unlike the other Apollo crews, Apollo 15 astronauts chose to sleep after their landing, which

Right: Commander David Scott salutes the US flag, which was deployed at the Hadley-Apennine landing site during the second EVA

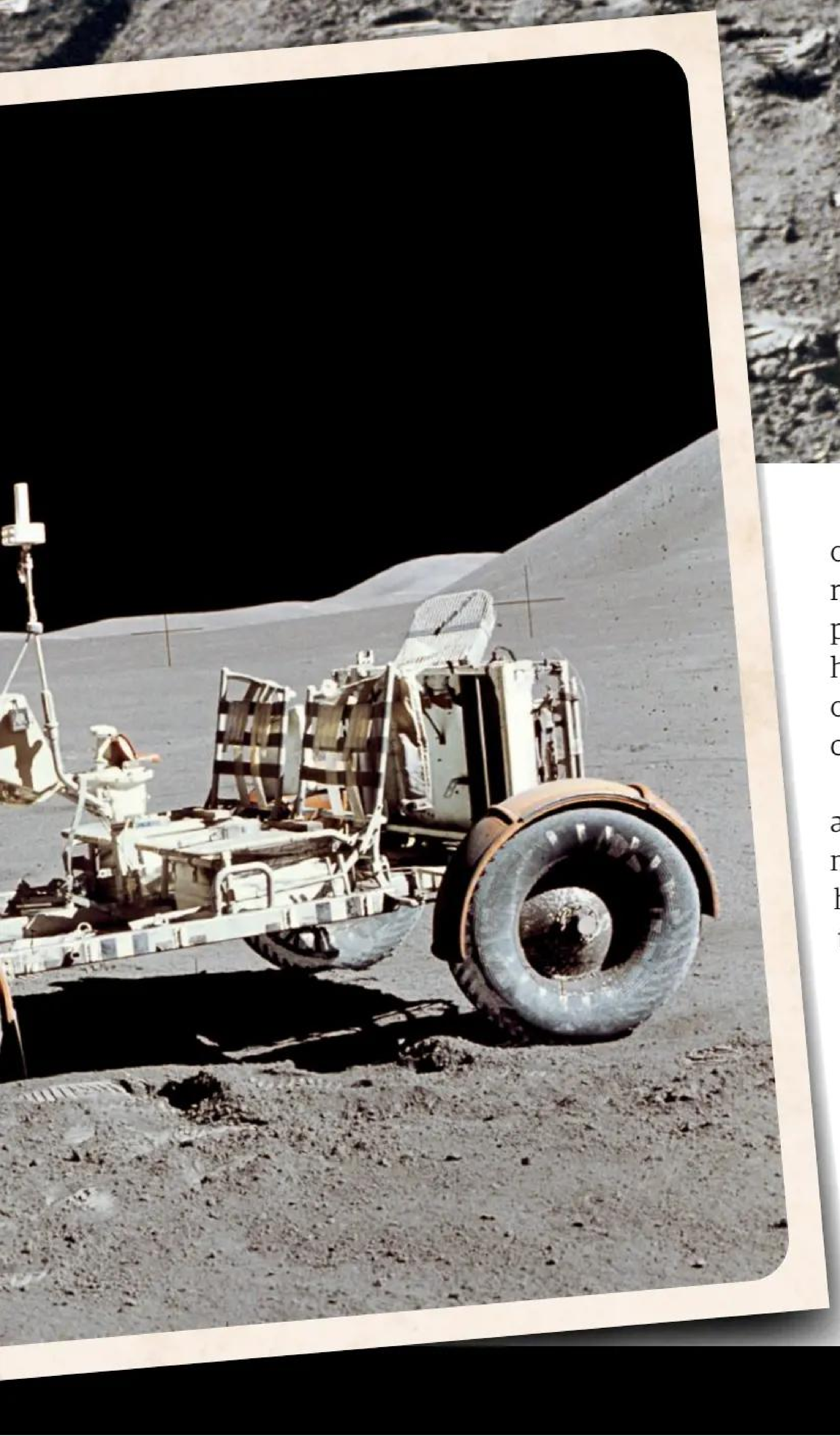


Right below: Apollo 15 saw the first use of the Lunar Roving Vehicle (LRV), or 'Moon buggy'



Left: The crew of Apollo 15, from left to right: Commander David Scott, Command Module pilot Alfred 'Al' Worden, and Lunar Module pilot James 'Jim' Irwin

> "The Earth reminded us of a Christmas tree ornament hanging in the blackness of space" **Jim Irwin**



occurred on July 30, instead of doing a moonwalk right away. The time to rest helped the crew preserve their energy for the longer mission. Before hitting the sack, Scott opened the hatch at the top of the lunar lander, Falcon, and took a series of camera shots to get a panoramic view of the site.

The next morning, Scott hopped down the ladder and looked at the field site surrounding him. "Man must explore. And this is exploration at its greatest," he said. Then, he and Irwin got to work unfolding the lunar roving vehicle from the side of Falcon.

Next came a test drive. It was no surprise that driving was a bumpy experience, given the rocks and mini-divots in the Moon's surface. The front-wheel drive didn't work, but Scott found he could manage with only the rear-wheel-drive system.

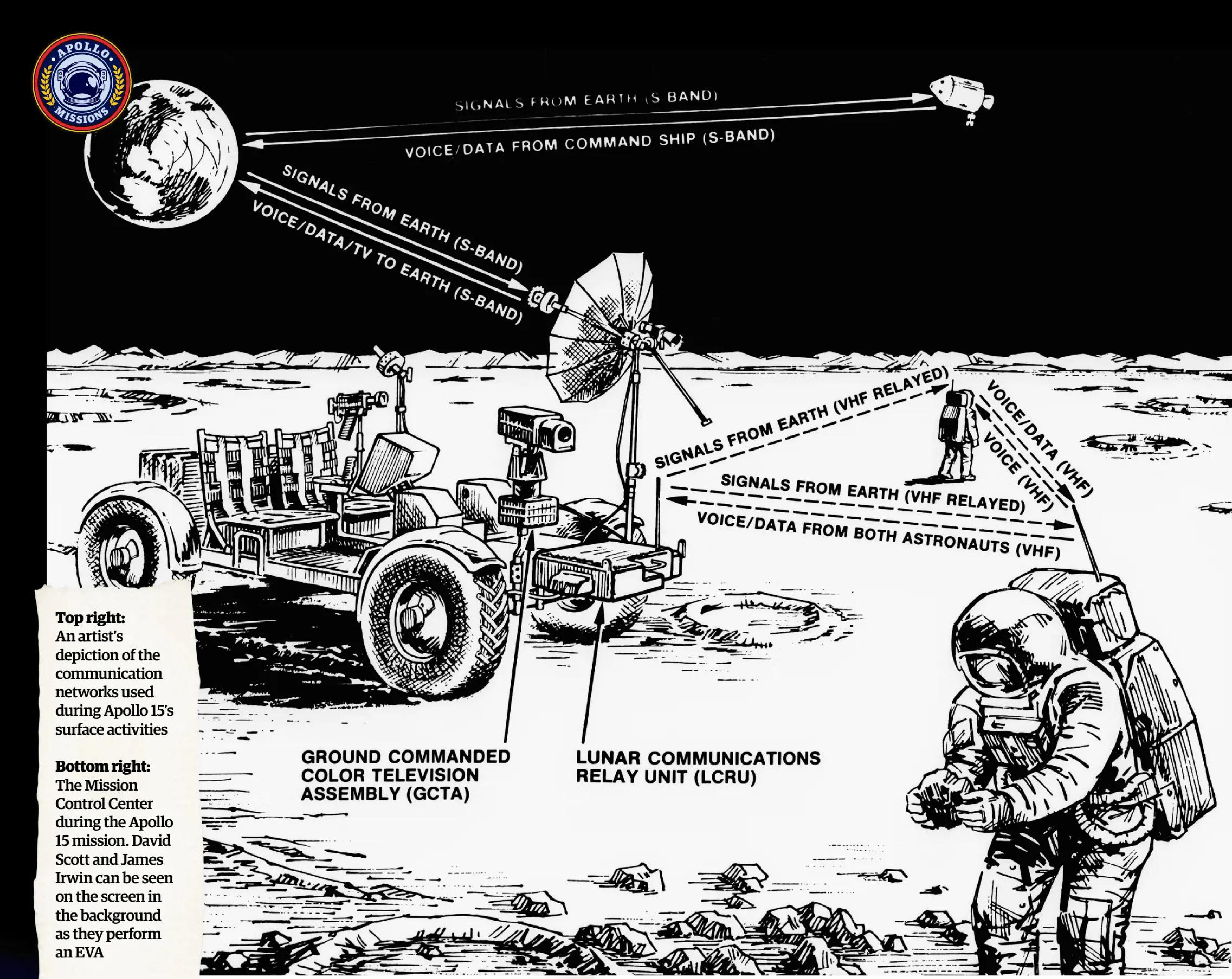
The astronauts drove the rover a total of 28 kilometres (17.5 miles). The crew had one main complaint: the seat belts, which were difficult to get on and off, because lunar gravity did not push the astronauts down easily to allow them to fasten the seatbelt over their spacesuits.

Scientific discovery

Irwin and Scott were on the hunt for anorthosites, which are believed to be the Moon's oldest rocks, and the astronauts found the material in spades during the second day on the lunar surface. At Spur Crater, the astronauts picked up four of these types of rocks. The best known of the bunch was later dubbed the Genesis Rock because of its ancient age, some 4.5 billion years old.

Back at the Falcon, Scott was supposed to drill down below the Moon's surface to get a "core sample" that would show the layers of rock underneath the surface. The regolith was packed

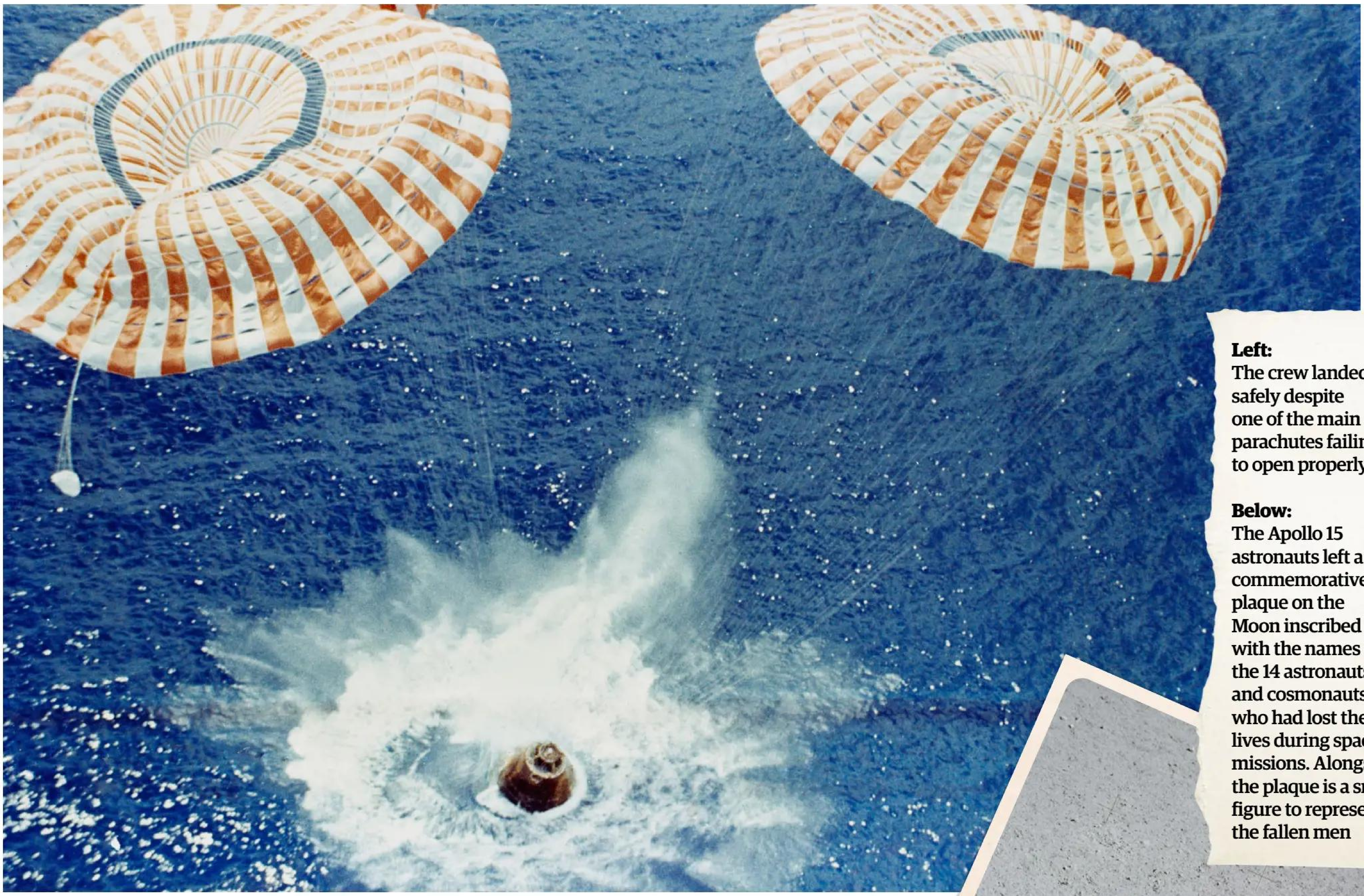
© NASA; JSC


SIGNALS FROM EARTH (S BAND)
VOICE/DATA FROM COMMAND SHIP (S-BAND)
SIGNALS FROM EARTH (S-BAND)
VOICE/DATA/TV TO EARTH (S-BAND)
SIGNALS FROM EARTH (VHF RELAYED)
VOICE/DATA (VHF)
VOICE (VHF)
SIGNALS FROM EARTH (VHF RELAYED)
VOICE/DATA FROM BOTH ASTRONAUTS (VHF)
GROUND COMMANDED COLOR TELEVISION ASSEMBLY (GCTA)
LUNAR COMMUNICATIONS RELAY UNIT (LCRU)

Top right: An artist's depiction of the communication networks used during Apollo 15's surface activities

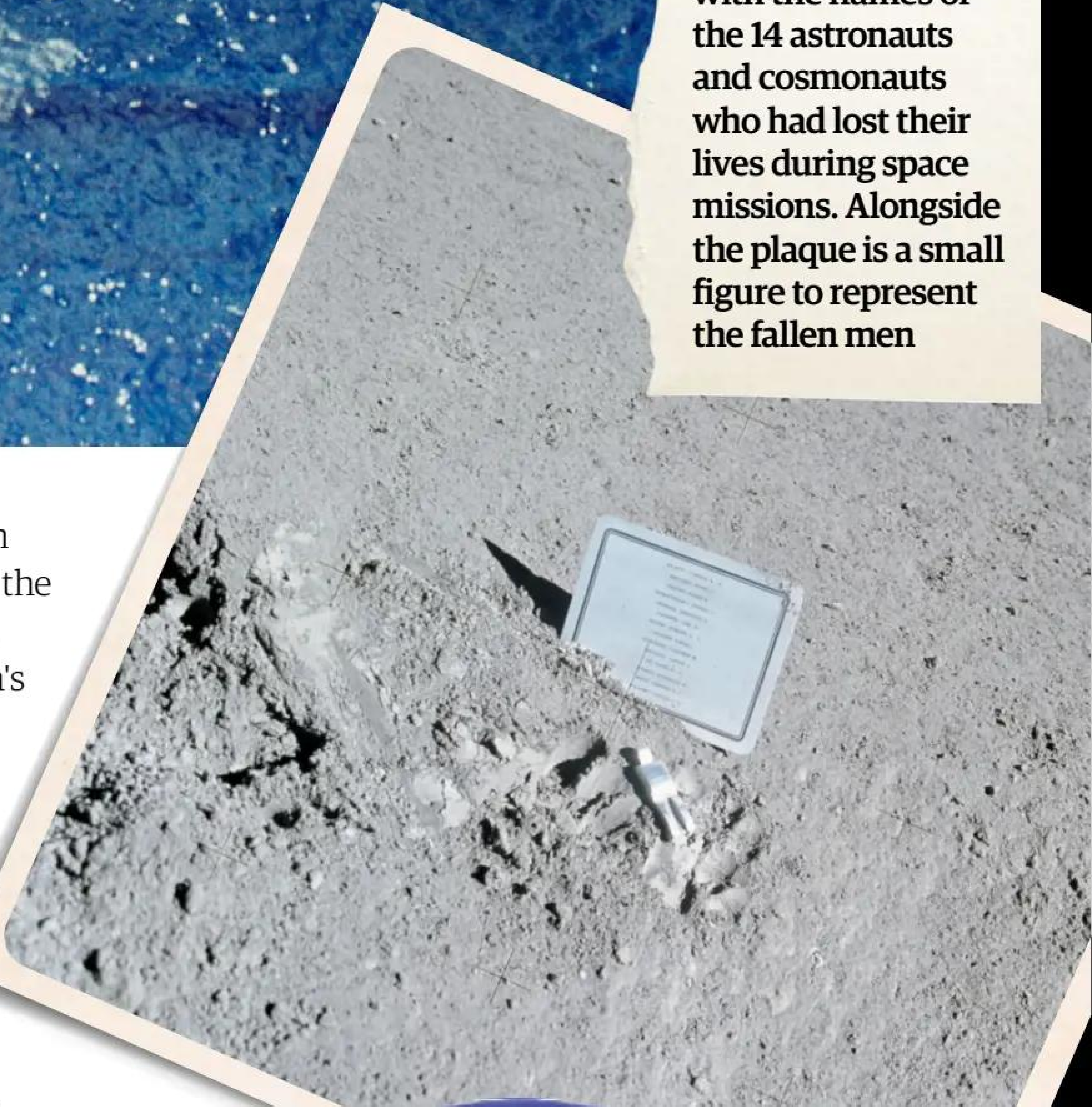
Bottom right: The Mission Control Center during the Apollo 15 mission. David Scott and James Irwin can be seen on the screen in the background as they perform an EVA

Below: This Moon rock sample, collected by Apollo 15 astronauts, is made of basalt fragments welded together by a dark glassy matrix that was produced by melting from a meteorite impact. MIT and Rutgers scientists studied the sample to glean new insights about the Moon's magnetic field



Left:
The crew landed safely despite one of the main parachutes failing to open properly

Below:
The Apollo 15 astronauts left a commemorative plaque on the Moon inscribed with the names of the 14 astronauts and cosmonauts who had lost their lives during space missions. Alongside the plaque is a small figure to represent the fallen men



tight, and it was hard to get the drill in far enough. Scott, who was tired from seven hours of work outside, simply didn't have the energy to pull the drill back out.

NASA ordered him to leave it until the next day. After Irwin and Scott went outside for their third spacewalk, both of them struggled to withdraw the core, but they succeeded.

After a geologically focused trip to Hadley Rille, the astronauts returned to their lunar lander, Antares. Scott then performed a small scientific experiment in front of the TV camera in honour of Galileo Galilei, dropping a feather and hammer on the lunar surface. Galileo is said to have dropped weights from the Leaning Tower of Pisa in the 17th century to demonstrate that objects of different mass fall at the same rate.

When the feather and hammer struck regolith at the same time, the mission's control crew applauded. "Nothing like a little science on the Moon," Scott said.

While Scott and Irwin toiled on the surface, Worden contributed his own observations from above. From the Command Module Endeavour, Worden excitedly described a crater called Littrow, which scientists of the time believed may have once been part of a volcanic region. Later, Apollo 17 landed at Littrow.

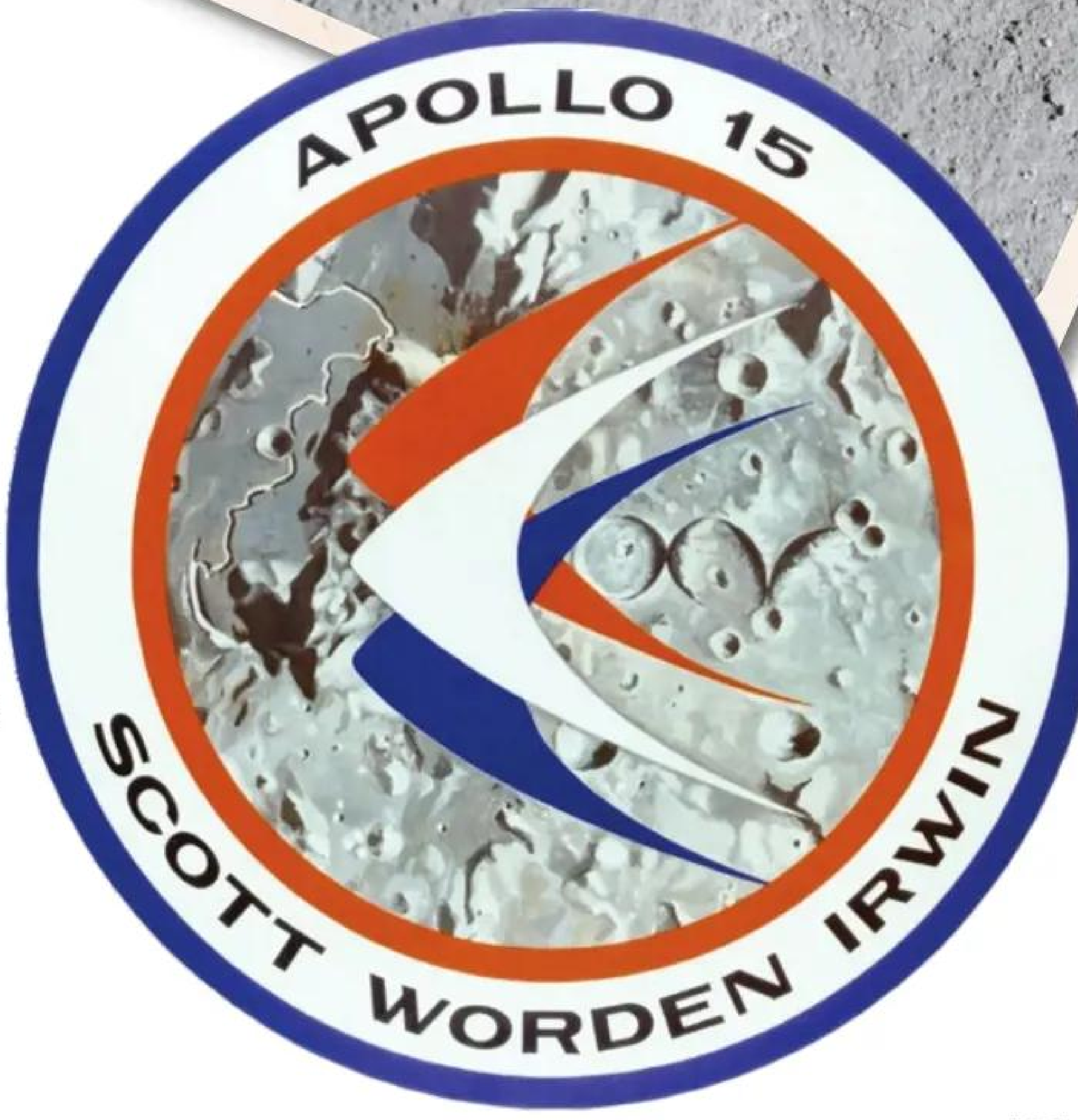
The crew left the surface of the Moon on 2 August, and for the first time, the liftoff was seen on Earth, broadcast via the television camera on the lunar rover. Just before they left lunar orbit, the crew launched the Particles and Fields satellite. This craft was designed to investigate the Moon's mass and gravitational variations, the particle composition of space near the Moon, and the interaction of the Moon's magnetic field with that of Earth.

All told, Apollo 15's Moon-roving astronauts spent 18 hours 37 minutes working on the lunar surface, almost equal to the total time spent in lunar orbit by the Apollo 8 crew. The Apollo 15 team set other records as well, including the longest time in lunar orbit - about 145 hours - and longest lunar mission, at 295 hours. The crew returned to Earth on 7 August, bringing back a geologic bonanza for scientists and positioning NASA for even more ambitious missions to come.

Apollo 15 legacy

Endeavour is located at the National Museum of the US Air Force at Wright-Patterson Air Force Base in Dayton, Ohio, while the upper stage of Falcon hit the Moon - as planned - on 3 August 1971. The 50th anniversary of the Apollo 15 mission is in 2021.

Apollo 15 kicked off the most ambitious lunar landings, with the remaining crews spending several days on the Moon's surface and hauling home a geological treasure.



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NASA'S MOON BUGGY

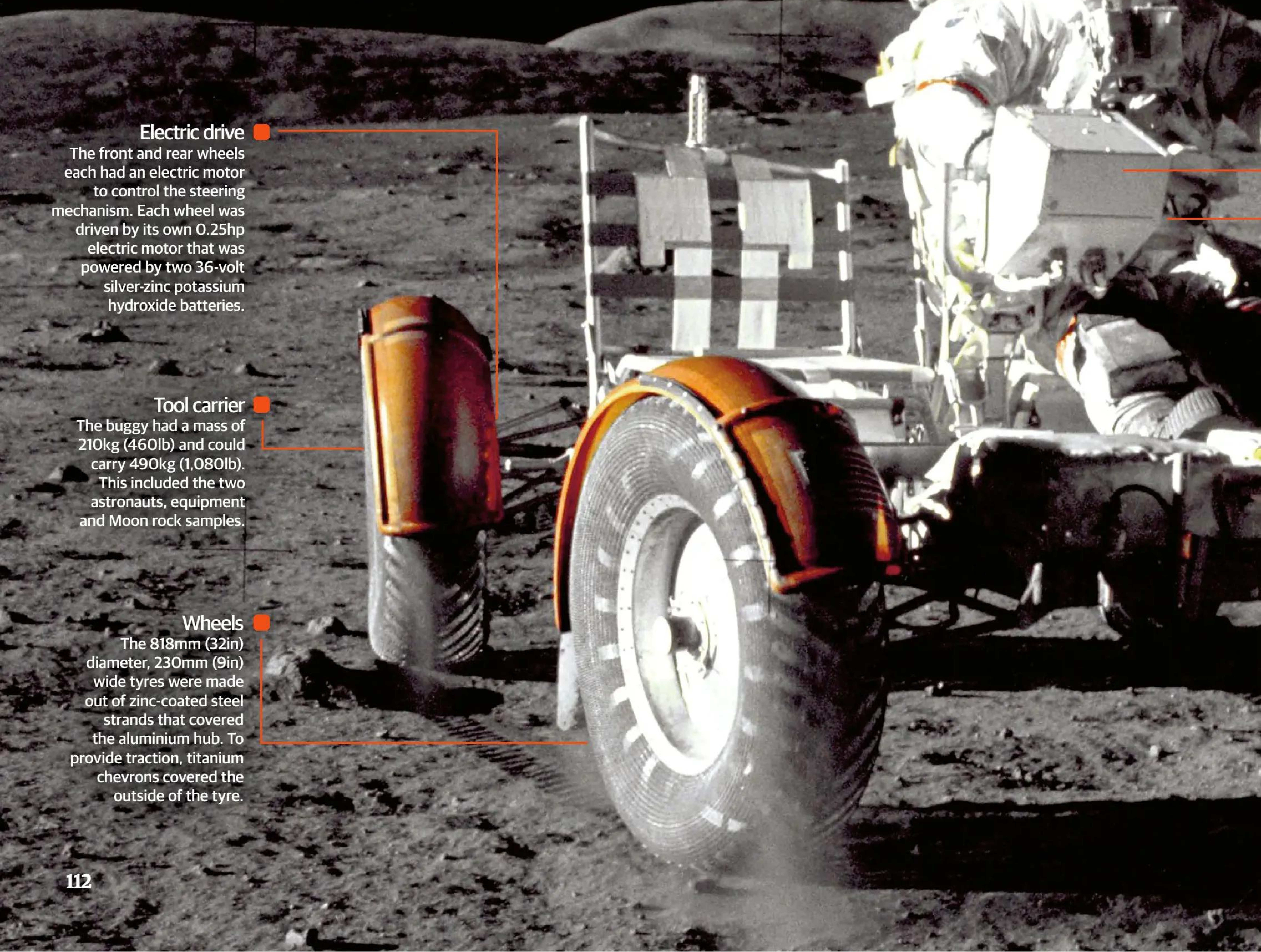
This small, four-wheel-drive, electric-powered buggy may look flimsy, but this intrepid vehicle is also the most expensive car in the history of humankind

Written by Nigel Watson

Officially known as the Lunar Roving Vehicle (LRV), NASA's state-of-the-art, $38-million-dollar Moon buggy was more spacecraft than regular vehicle. Its designers were tasked with producing a buggy that could carry two astronauts in heavy spacesuits, along with their scientific equipment, over the rugged lunar terrain where temperatures can range from +/-120 degrees Celsius (+/-250 degrees Fahrenheit) and the gravity is one-sixth the strength that it is on Earth.

To fit the buggy inside the 1.8x1.2-metre (6x4-foot) Quadrant 1 bay of the Descent Stage of the Lunar Module, the wheels were folded inwards and the whole body was folded in half. A set of ropes, cloth tapes, pulleys and springs enabled it to be swung out from the craft, and the wheels and body semi-automatically snapped into place. It took the Apollo 15 astronauts 26 minutes to deploy the rover in this fashion – ten minutes longer than originally planned.

The buggy was the size of a small car at 3.1 metres (10.1 feet) long, 1.83 metres (six feet) wide, 1.14 metres (3.7 feet) high. It didn't have a roof and the seats were like webbed patio furniture with Velcro strips on the surface. The astronauts had special spacesuits that could bend at the waist to enable them to sit in the vehicle, and the main steering and speed control was a T-shaped handle that could be easily operated while wearing bulky spacesuit gloves.



Electric drive
The front and rear wheels each had an electric motor to control the steering mechanism. Each wheel was driven by its own 0.25hp electric motor that was powered by two 36-volt silver-zinc potassium hydroxide batteries.

Tool carrier
The buggy had a mass of 210kg (460lb) and could carry 490kg (1,080lb). This included the two astronauts, equipment and Moon rock samples.

Wheels
The 818mm (32in) diameter, 230mm (9in) wide tyres were made out of zinc-coated steel strands that covered the aluminium hub. To provide traction, titanium chevrons covered the outside of the tyre.

Each wheel had its own electric motor, so that if one or more failed the buggy was still driveable. The front and rear wheels each had their own steering motor, with the option to steer with four wheels or with just the front or rear wheels. The buggy had a turning circle of 3.1 metres (10.1 feet) and had an average speed of nine kilometres (5.6 miles) per hour. During the Apollo 17 mission, Eugene Cernan set the speed record for the buggy at 18 kilometres (11.2 miles) per hour.

Only three buggies ever flew to the Moon, on the Apollo 15, 16 and 17 missions. On each mission, they made three separate journeys beyond the Lunar Module, to a maximum distance of 7.6 kilometres (4.7 miles). It was a very stable vehicle, although under the low gravity the wheels had a tendency to float off the ground and return to the Lunar surface much more slowly than expected.

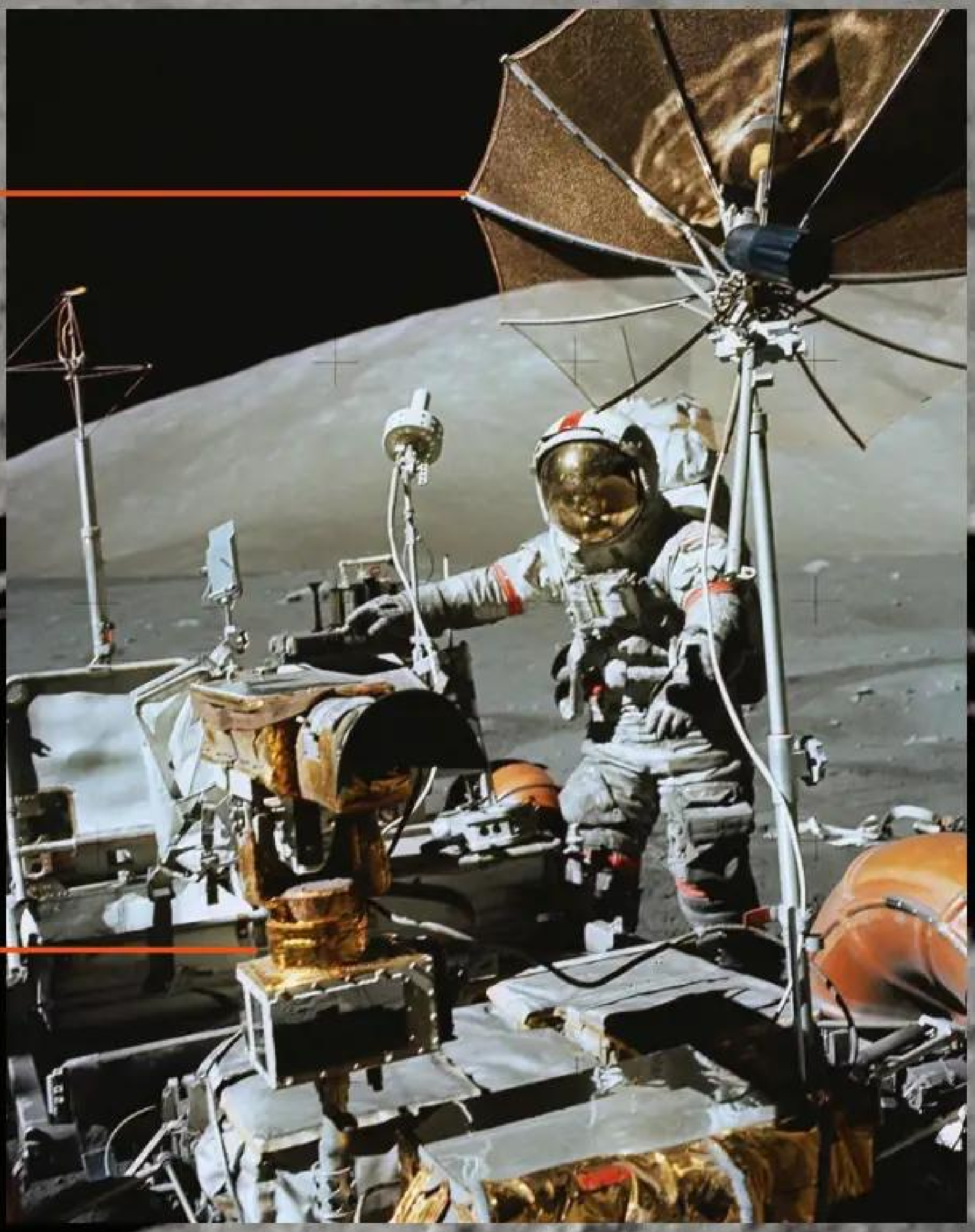
It only took 17 months to design, test and build the buggy at a cost of $38 million USD (£24 million), making it the most costly car in history. Nonetheless, it was a great success as it enabled the Apollo 15 astronauts to explore four times more territory than the previous Apollo 11, 12 and 14 missions put together. As Apollo 15 astronaut Dave Scott put it: "I think the vehicle is about as optimum as you can build."

> "It only took 17 months to design, test and build the Moon buggy... at a cost of $38 million"

Control and display module
This displayed the heading, pitch and speed of the buggy, along with its power and temperature levels. A navigation computer using data from an odometer and a gyroscope kept track of where it was in relation to the Lunar Module.

Controls
A T-handle control could be operated by either crewmember, to turn the buggy left or right, accelerate forwards, reverse or apply the parking brake.

Chassis
It had a three-part, 3.1m (10.1ft) long chassis, made out of aluminium alloy tubing. It was hinged to enable it to be folded inside the Descent Stage of the Lunar Module.



Antenna
The high-gain antenna sent TV data, and the low-gain antenna sent voice data back to Mission Control. The high-gain antenna was unable to transmit TV pictures when the buggy was moving.

Television camera
Mission Control back on Earth operated this remote-control colour TV camera, so they could view the local terrain to provide the astronauts with navigation advice.

NASA's penultimate Moon mission led to some rocky revelations about the Moon's origins

APOLLO 16

Exploring the highlands

Reported by Elizabeth Howell

© NASA; JSC

Apollo 16 was the second-to-last mission of the Apollo program and the fifth to land humans on the Moon. Apollo 16 launched on 16 April 1972, and landed at the Descartes highlands, a lunar highland area near the Descartes crater. While there, the crew searched for volcanic rocks.

Although the astronauts didn't come back with the rocks they were searching for, their skill in picking out geological targets and their ability to cope with changing fortunes made this mission a highlight of scientific discovery on the Moon.

The Apollo 16 astronauts

Cmdr John Young was among NASA's most seasoned astronauts, having already spent a decade in the career. The former US Navy aviator flew twice in the Gemini program, flying as co-pilot in the first mission (Gemini 3, 1965) and commanding Gemini 10 (1966), which rendezvoused with two separate target vehicles in space. With the Apollo program, Young was the Command Module pilot on Apollo 10 (1969) and helped perform the first docking above the surface of the Moon. After Apollo, Young went on to command the first space shuttle mission (STS-1, 1981) and a second space shuttle mission in 1983, called STS-9.

Apollo 16 Command Module pilot Ken Mattingly was selected in 1966. He got a second chance to go to the Moon after he was pulled from the Apollo 13 mission because of a medical concern. Before joining NASA, he was a Navy aviator. After Apollo 16, Mattingly commanded two space shuttle missions: STS-4 in 1982 and STS-51C in 1985.

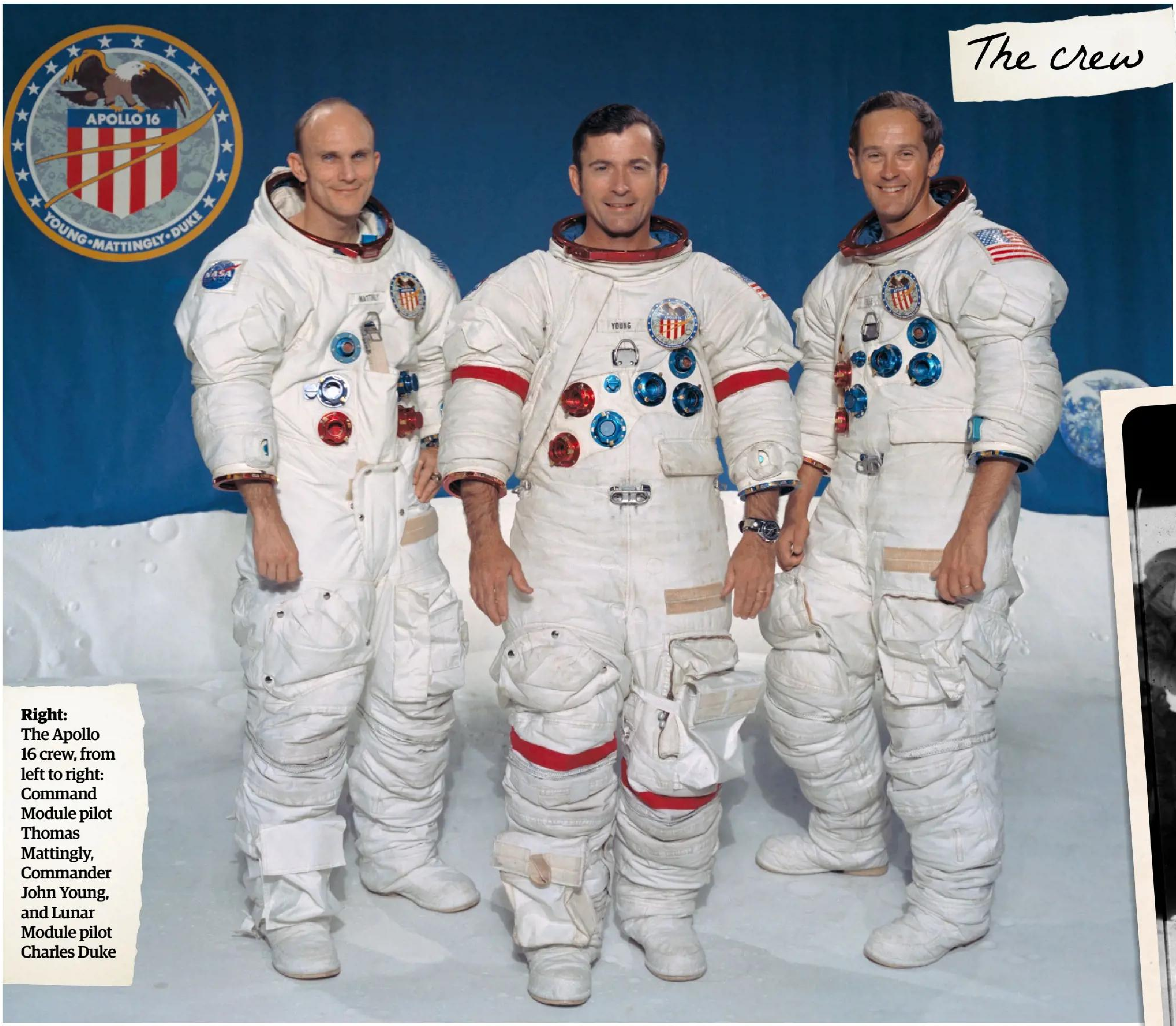
Charles Duke, the Lunar Module (or lunar lander) pilot, is perhaps best known as being the CapCom during the Apollo 11 landing, who said, "You've got a bunch of guys about to turn blue down here", after the crew landed with a few drops of fuel remaining. Duke was a U.S. Air Force pilot instructor when NASA selected him as an astronaut in 1966. Apollo 16 was Duke's only spaceflight.

Balky engine and snagged cable

Scientists suspected that Apollo 16's destination contained volcanic rocks. Geologists were hoping to get samples of these rocks to find out how the Moon's interior was formed.

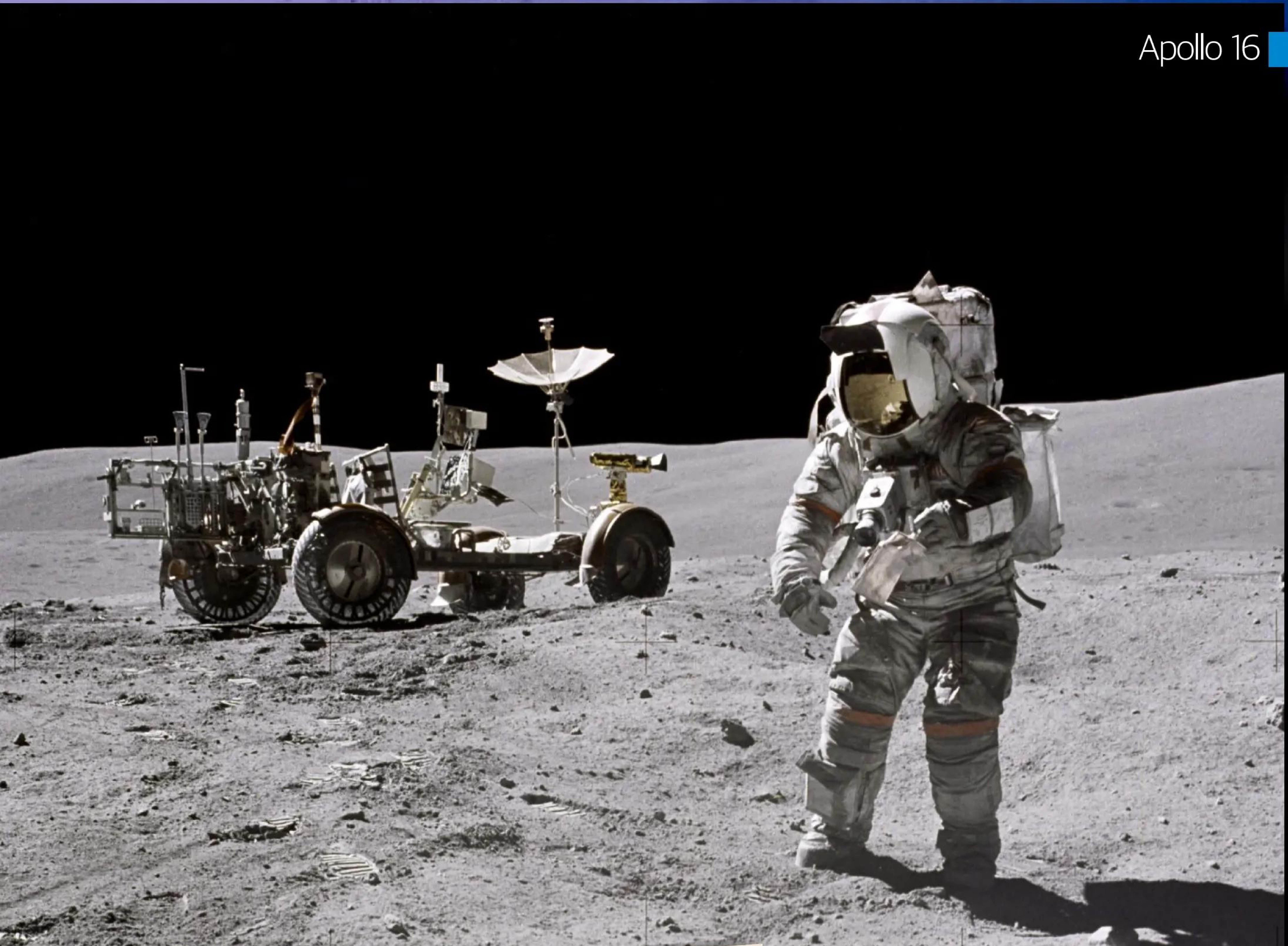
The spacecraft reached lunar orbit on 19 April. Shortly after the Lunar Module Orion separated from the Command Module Casper, Mattingly noticed that the Command Module engine was vibrating strangely when he touched one of the controls in the backup system.

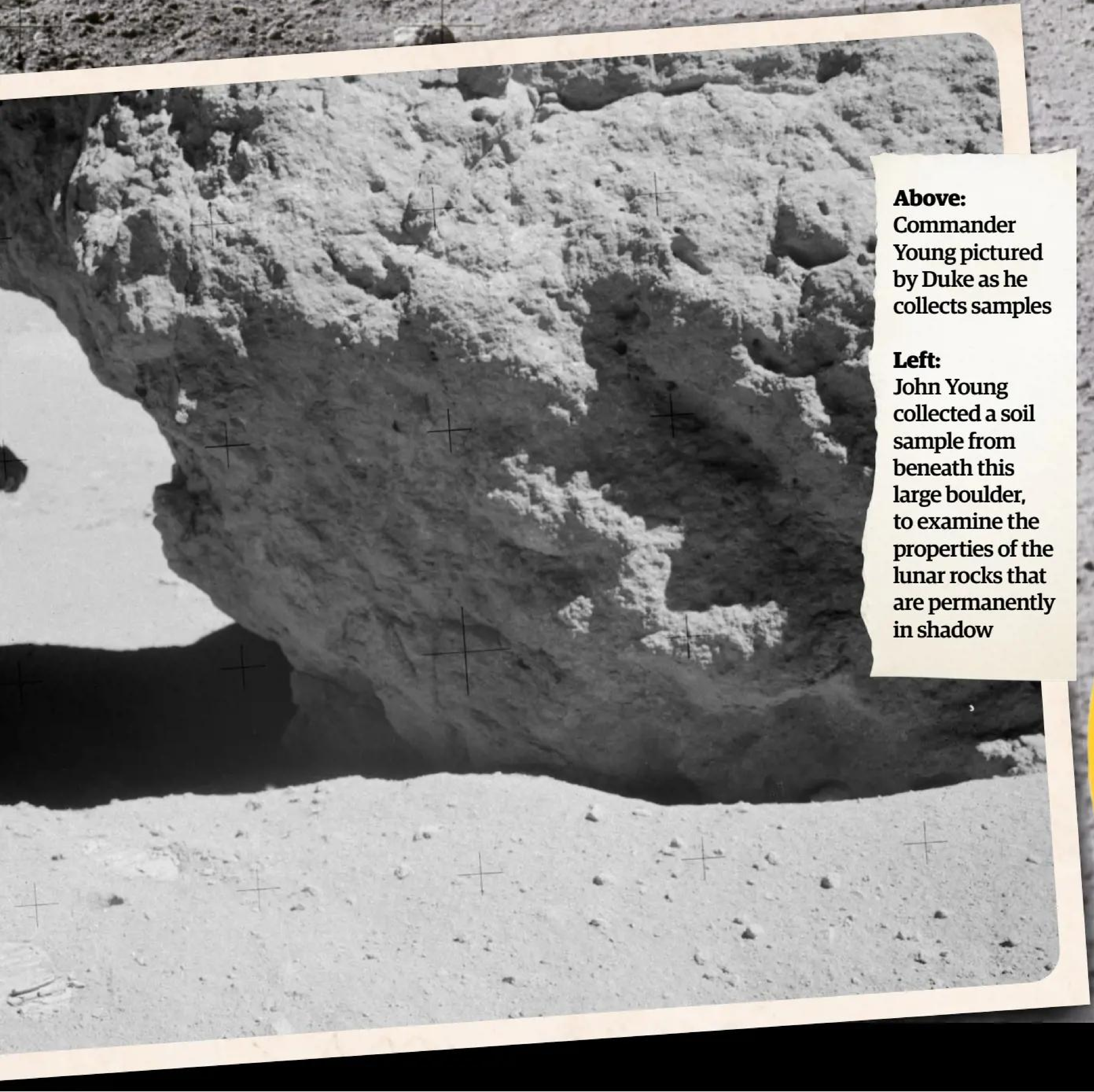
Uneasily, the crew circled the Moon for several hours in their two spacecraft as Mission Control decided whether it was safe to proceed. After analysing the data, Houston gave the thumbs-up, and Orion finally descended successfully to the Moon's surface.



The crew

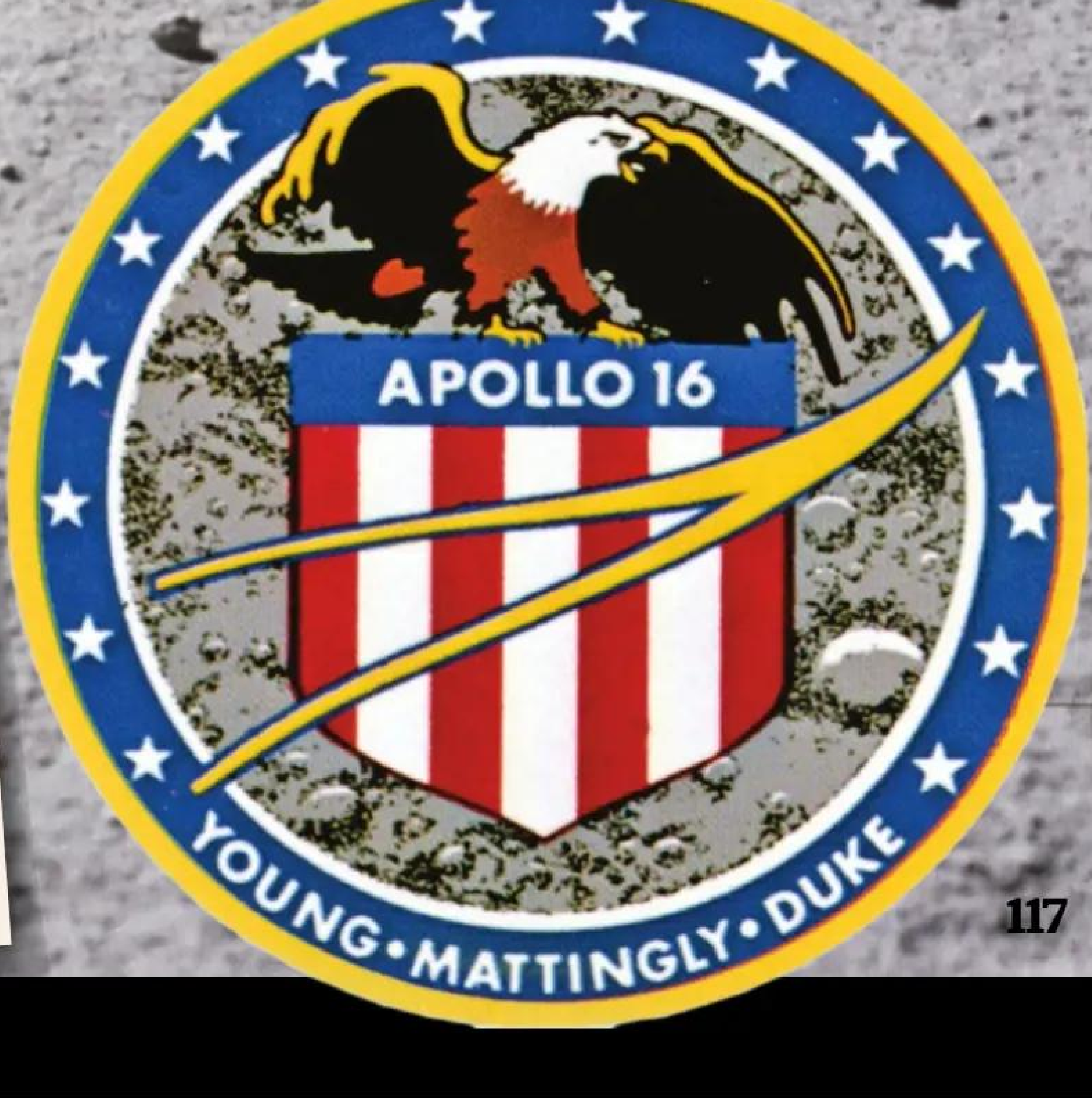
Right: The Apollo 16 crew, from left to right: Command Module pilot Thomas Mattingly, Commander John Young, and Lunar Module pilot Charles Duke





Above: Commander Young pictured by Duke as he collects samples

Left: John Young collected a soil sample from beneath this large boulder, to examine the properties of the lunar rocks that are permanently in shadow


APOLLO 16
YOUNG • MATTINGLY • DUKE

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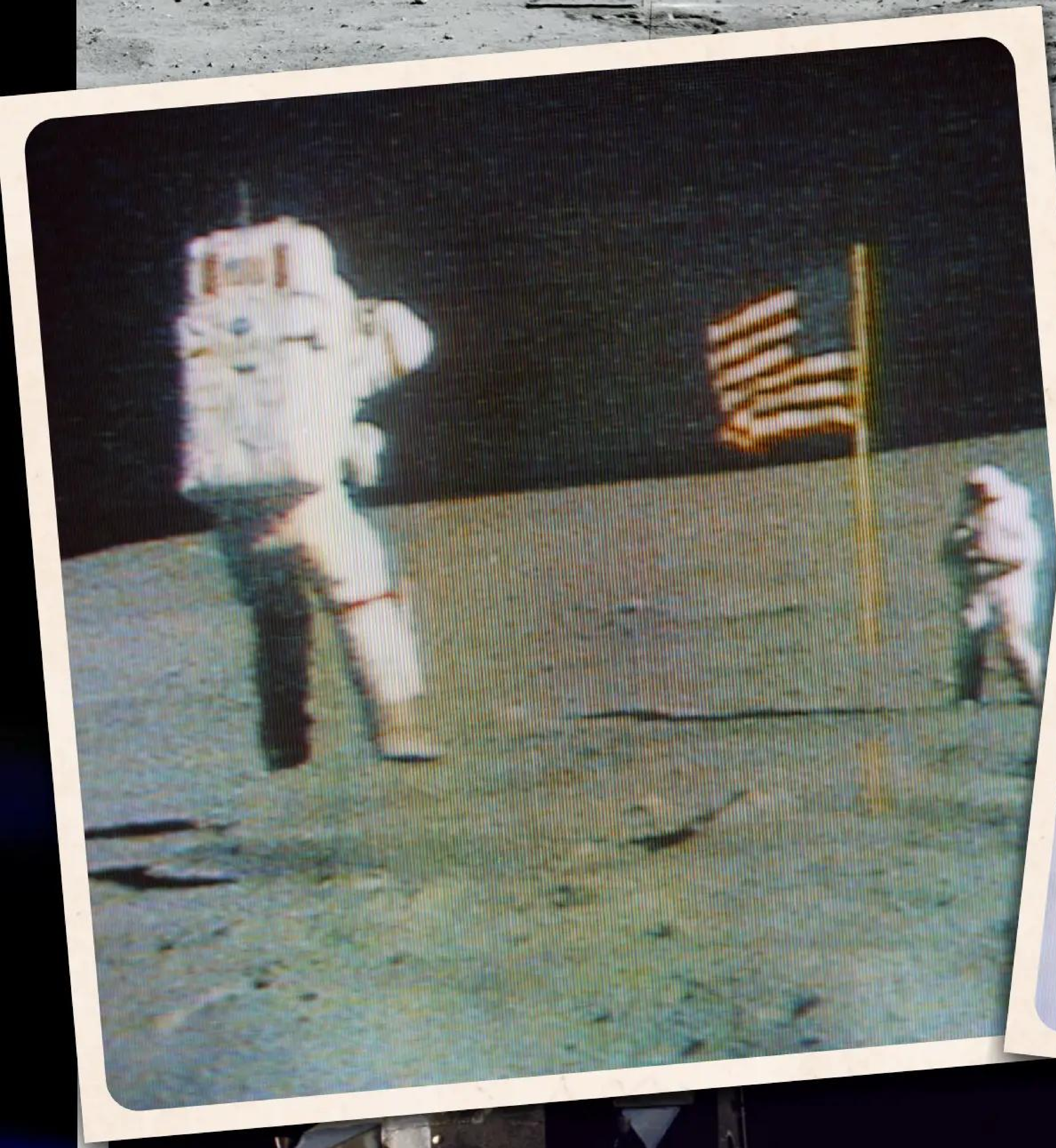
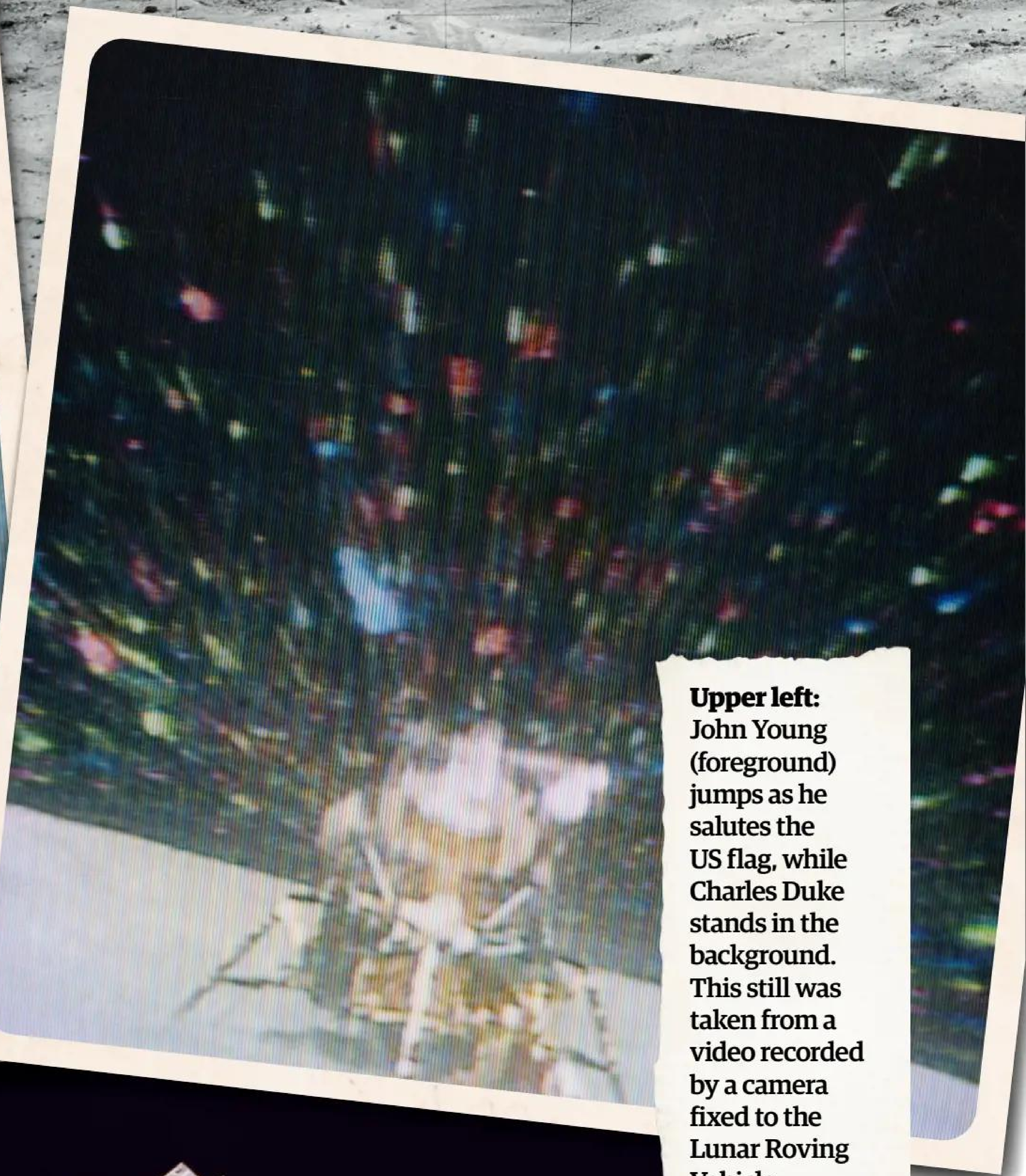
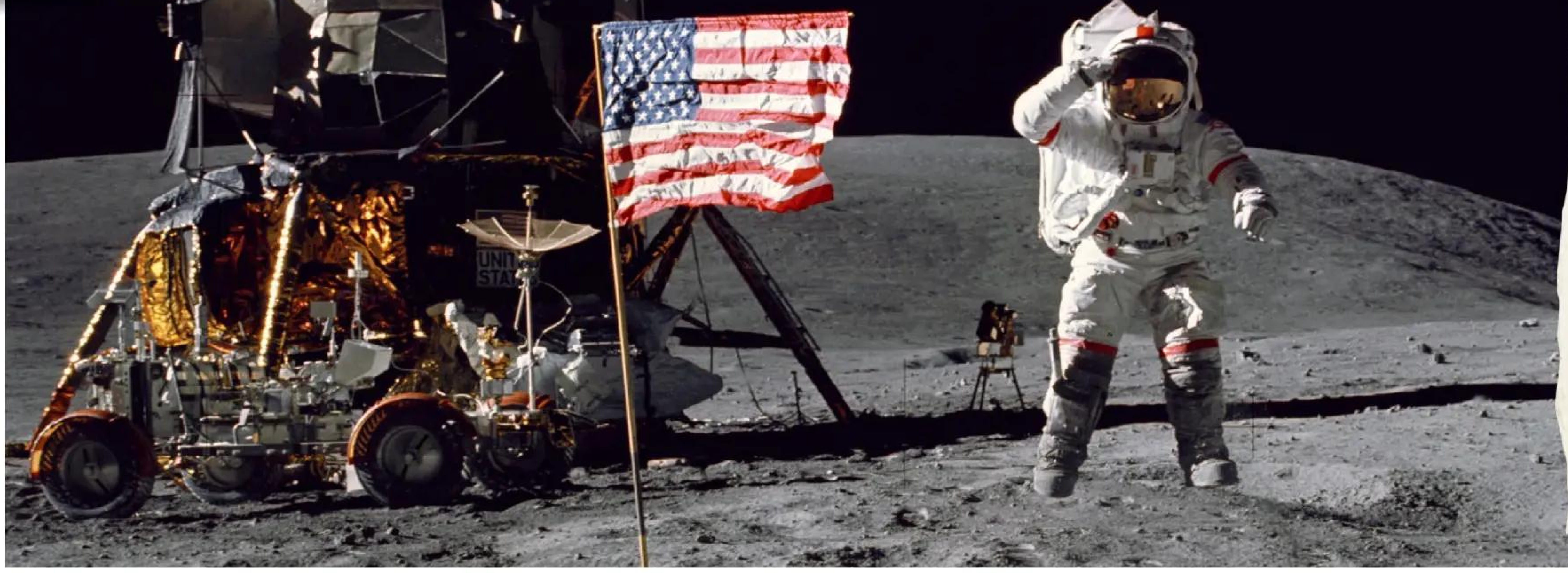
“Mysterious and unknown Descartes highland plains: Apollo 16 is going to change your image”

Cmdr John Young



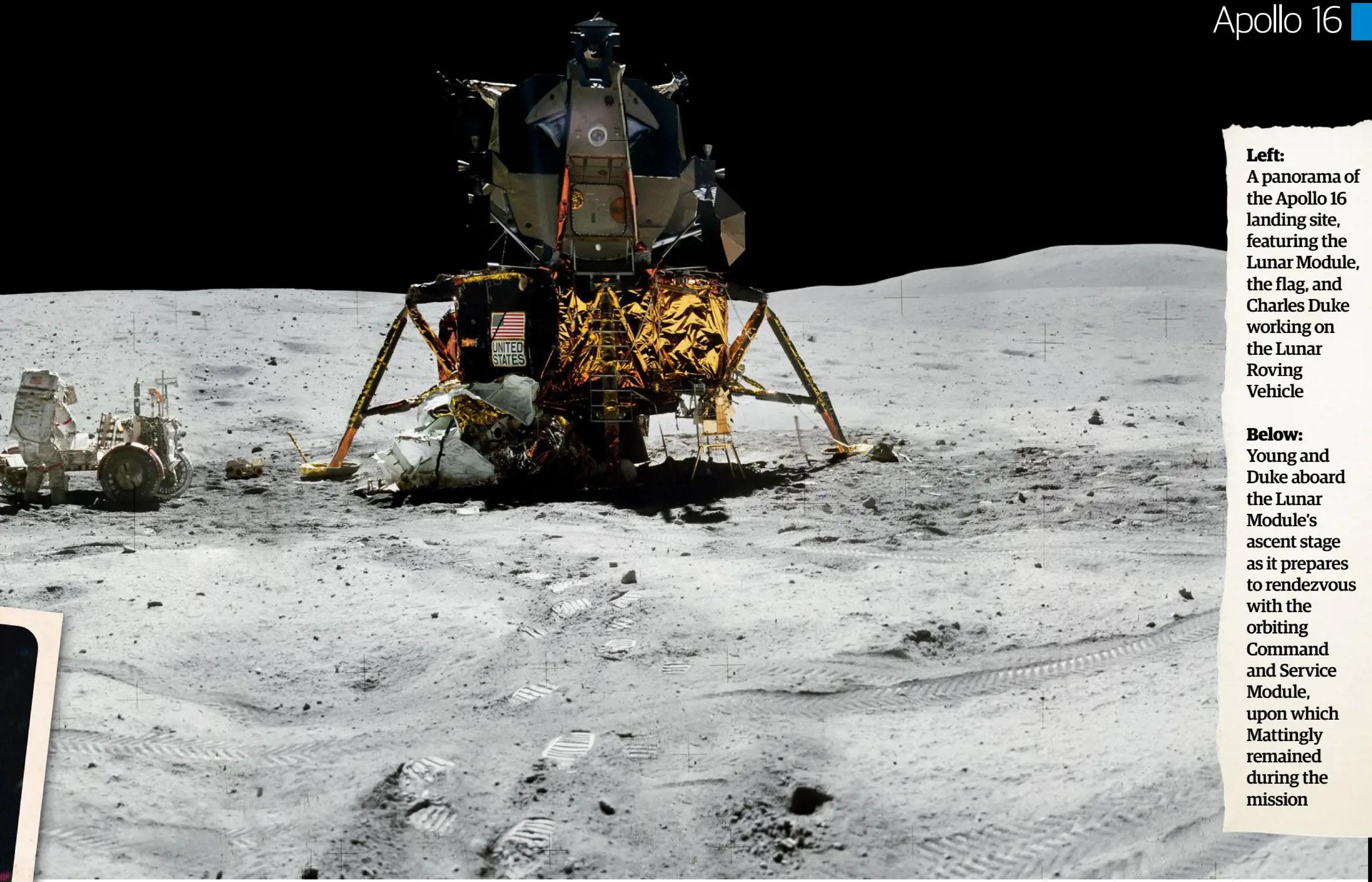




Upper left: John Young (foreground) jumps as he salutes the US flag, while Charles Duke stands in the background. This still was taken from a video recorded by a camera fixed to the Lunar Roving Vehicle

Below left: A photograph of Young's leaping salute, as taken by Duke

Above: The Lunar Roving Vehicle's video camera captures the Lunar Module during liftoff as it leaves the Moon on 22 April 1972



Left: A panorama of the Apollo 16 landing site, featuring the Lunar Module, the flag, and Charles Duke working on the Lunar Roving Vehicle

Below: Young and Duke aboard the Lunar Module's ascent stage as it prepares to rendezvous with the orbiting Command and Service Module, upon which Mattingly remained during the mission

The next day, Young stood on the Moon for the first time with his fists raised in happiness. "There you are, our mysterious and unknown Descartes highland plains. Apollo 16 is going to change your image," he said.

Duke and Young's first job was to deploy a package of several experiments on the surface to measure some key properties of the local environment. All Apollo astronauts knew how hard it was to see your feet and feel what they were touching through the bulky spacesuit. Nonetheless, Young accidentally pulled a vital cable free from a heat flow experiment when his boot snagged on the cable, ruining the experiment.

Apologising profusely, the astronauts finished setting up the package and moved on to their next tasks. They drove the lunar rover to two geological locations, finding only sedimentary breccia rocks, which are rocks composed of various mineral fragments, and not the volcanic ones geologists had hoped to find.

Breccias and a big rock

Duke and Young never found volcanic rocks while roaming around the Moon's surface. On their second day in the rover, they drove to a set of five craters on Stone Mountain, a large hill. While there, the astronauts collected rocks that showed how meteor impacts had kicked up debris to form the hills around them.

Observers of the Apollo 16 mission later commented on how self-assured the crew appeared as they used their equipment and walked around the Moon. The astronauts weren't afraid to kneel, jump high, or to pick up their rover and move it if it wasn't sitting in quite the right spot. Eight people had walked on the Moon before Apollo 16, and Young and Duke had learned from watching their extravehicular activities.

That's not to say everything went smoothly. For example, Young accidentally snagged his hammer against part of the dust guard of the rover and broke it off. This resulted in the astronauts being showered with rock-filled dust as they drove around the Moon's surface. But stoically, they adapted as best as they could.

On their third day on the Moon, the crew had to cut operations short because they landed so late on their first day, but they squeezed in the time to visit North Ray Crater. While they were working, they spotted a large rock in the distance and went sprinting toward it. Amused mission controllers watched cheerfully as the astronauts got smaller and smaller on the TV screen. "And as our crew sinks slowly in the west," said astronaut and geologist Jack Schmitt, which drew laughter from the others in the control room.

The rock, later dubbed House Rock, was a gigantic breccia (a rock composed of a conglomerate of broken minerals), showing the odds of any volcanic activity in the region were slim.

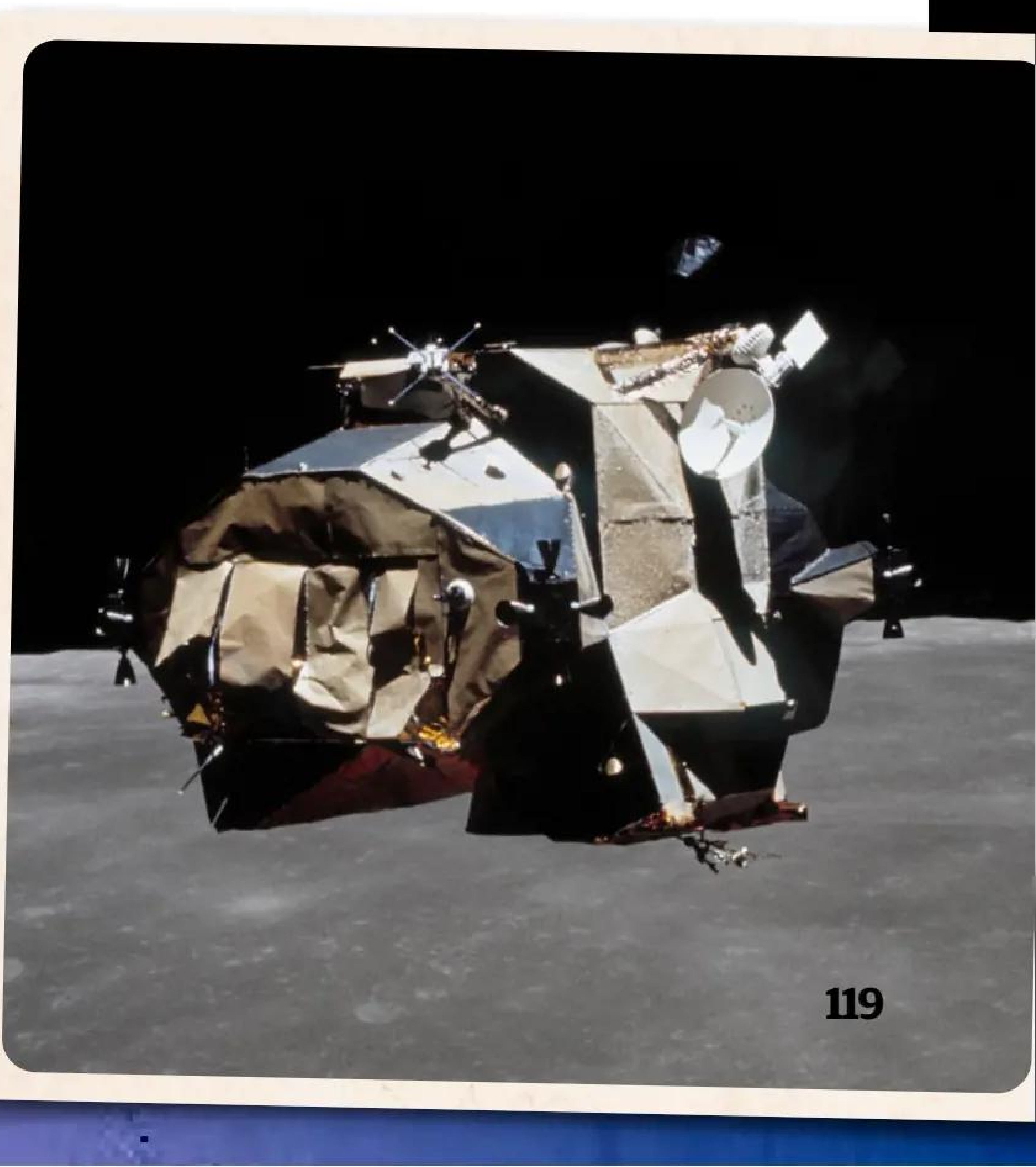
The Command Module Casper landed safely in the Pacific on 27 April, carrying a load of rocks that turned out to be mostly breccias. Although the crew found something different from what experts had expected, the treasure trove of Moon rocks would provide scientists with many hours of study in the decades to come.

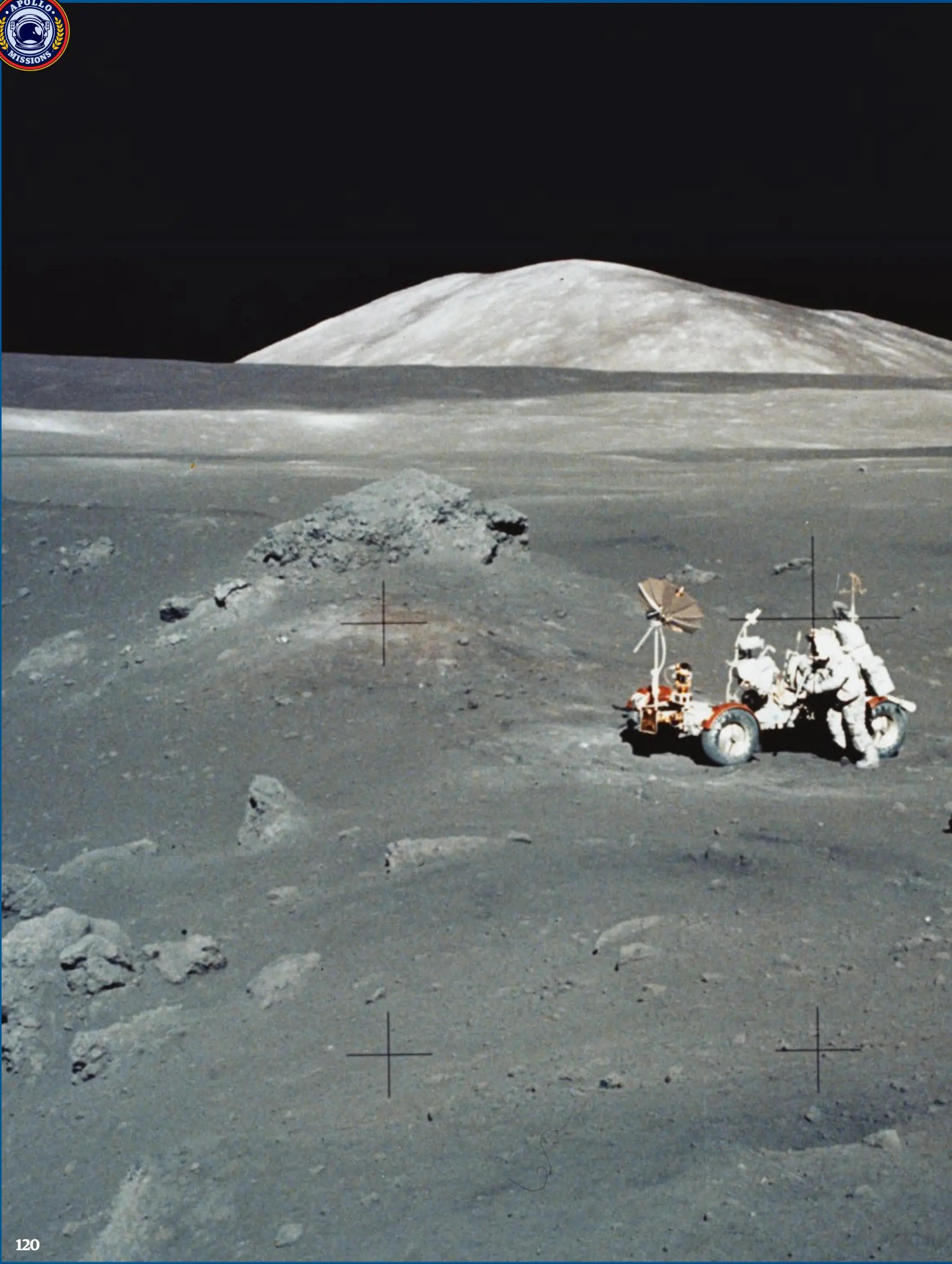
Apollo 16's legacy

The 50th anniversary of Apollo 16 is in 2022. Casper is kept at the Alabama Space and Rocket Center in Huntsville. Orion's upper stage impacted the Moon, although NASA is unsure of the exact location.

On his final day on the lunar surface, Duke placed a photo of his family on the ground and took pictures of it. The photo shows Duke, his wife, Dorothy, and their sons, Charles and Thomas. He left the photo on the Moon, where it remains today.

© NASA; JSC





The project's final mission marked the end of space exploration's defining era

APOLLO 17

Last Men on the Moon

Reported by Elizabeth Howell

© NASA; JSC

Apollo 17 took the 11th and 12th people to the surface of the Moon and marked the end of the Apollo programme. By the time the mission launched, on 7 December 1972, public interest in space exploration had declined and the government had shifted focus to the Vietnam War. These and many other factors brought the program to a close, even though three more flights were originally planned.

Apollo 17 was the first mission to include a scientist in its crew. Geologist Harrison 'Jack' Schmitt was one of the first six scientist-astronauts selected in 1965 amid immense pressure to do so from the National Academy of Sciences, which was worried that only test pilots would get the opportunity to walk on the Moon.

When it came time to select the final crew, Schmitt was chosen over Joe Engle, who was a backup pilot for Apollo 14 and would have been next in the rotation to fly. The usual procedure was for an astronaut to back up a mission and then fly as prime astronaut on the third mission after his backup. Crewmates Ron Evans and Eugene Cernan were upset for Engle. However, they were pleased at the capabilities Schmitt, a geological trainer for other Moon-bound astronauts, showed on the job.

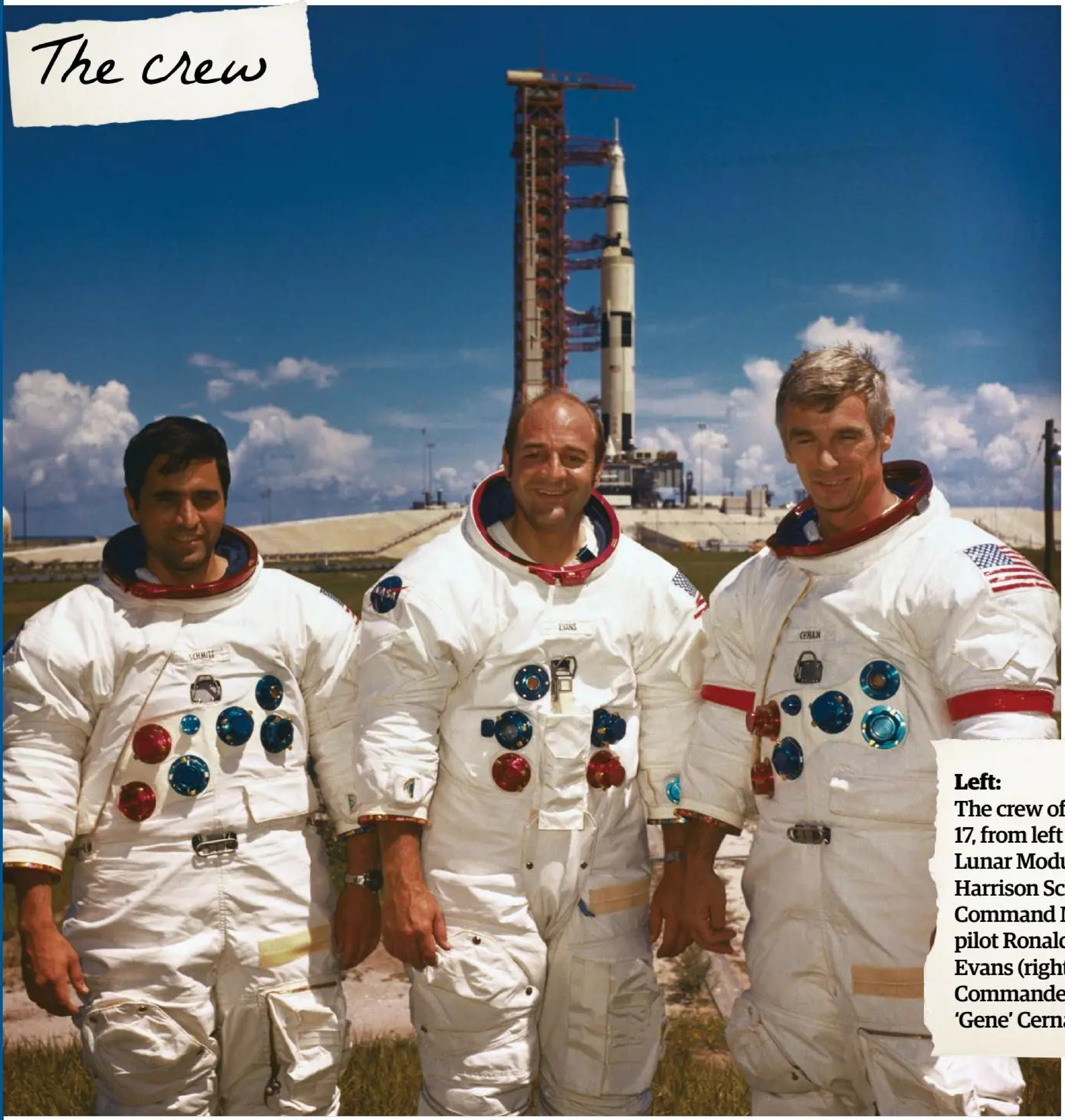
Evans, the Command Module pilot, was on his first mission to space. He was on combat duty in Vietnam in April 1966 when he found out he was selected as an astronaut. Evans had not only flown in combat, but was also a combat pilot instructor.

Mission Cmdr Cernan, a former US Navy pilot, had faced many obstacles in space. On his first flight, Gemini 9 in 1966, he did a spacewalk that exhausted him because there weren't enough handholds to perform his work in microgravity. On his second flight, Apollo 10 in 1969, the Lunar Module briefly spun unpredictably as Cernan and crewmate Tom Stafford did a practice descent to the surface. He was a seasoned pilot and felt ready to command his crew on the most challenging Apollo mission yet.

Assessing and accessing the landing site

With the later Apollo missions so focused on science, and with a geologist on board for Apollo 17, much consideration went into choosing the lunar valley called Taurus-Littrow as Apollo 17's destination. The geological variety of that valley finally and decisively tilted the decision in favour of the location. Points of interest to scientists in Taurus-Littrow included Shorty Crater – believed to hold evidence of past volcanic vents – and several large boulders spotted in photographs taken by the Apollo 15 crew.

The crew



Left:
The crew of Apollo 17, from left to right: Lunar Module pilot Harrison Schmitt, Command Module pilot Ronald Evans (right), and Commander Eugene 'Gene' Cernan

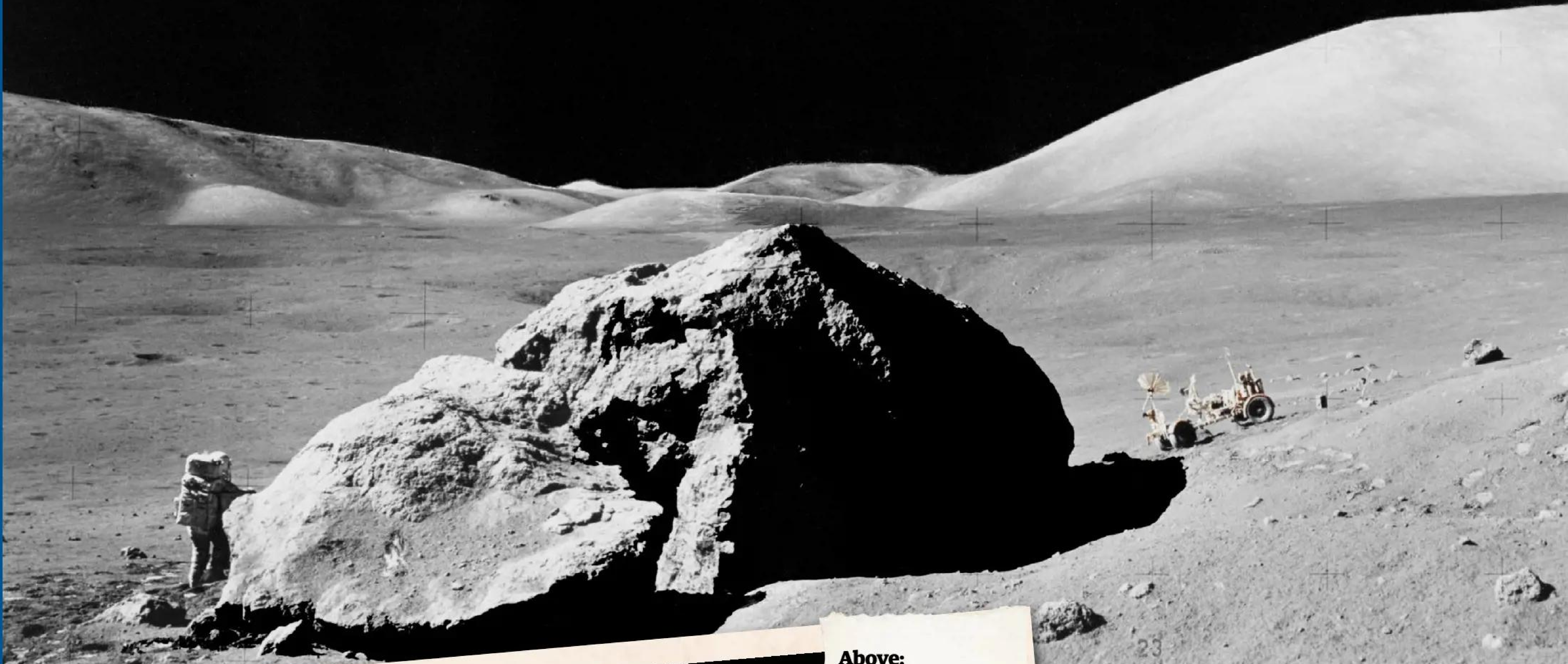
Right: Cernan (left) and Evans (right), in low gravity aboard Apollo 17

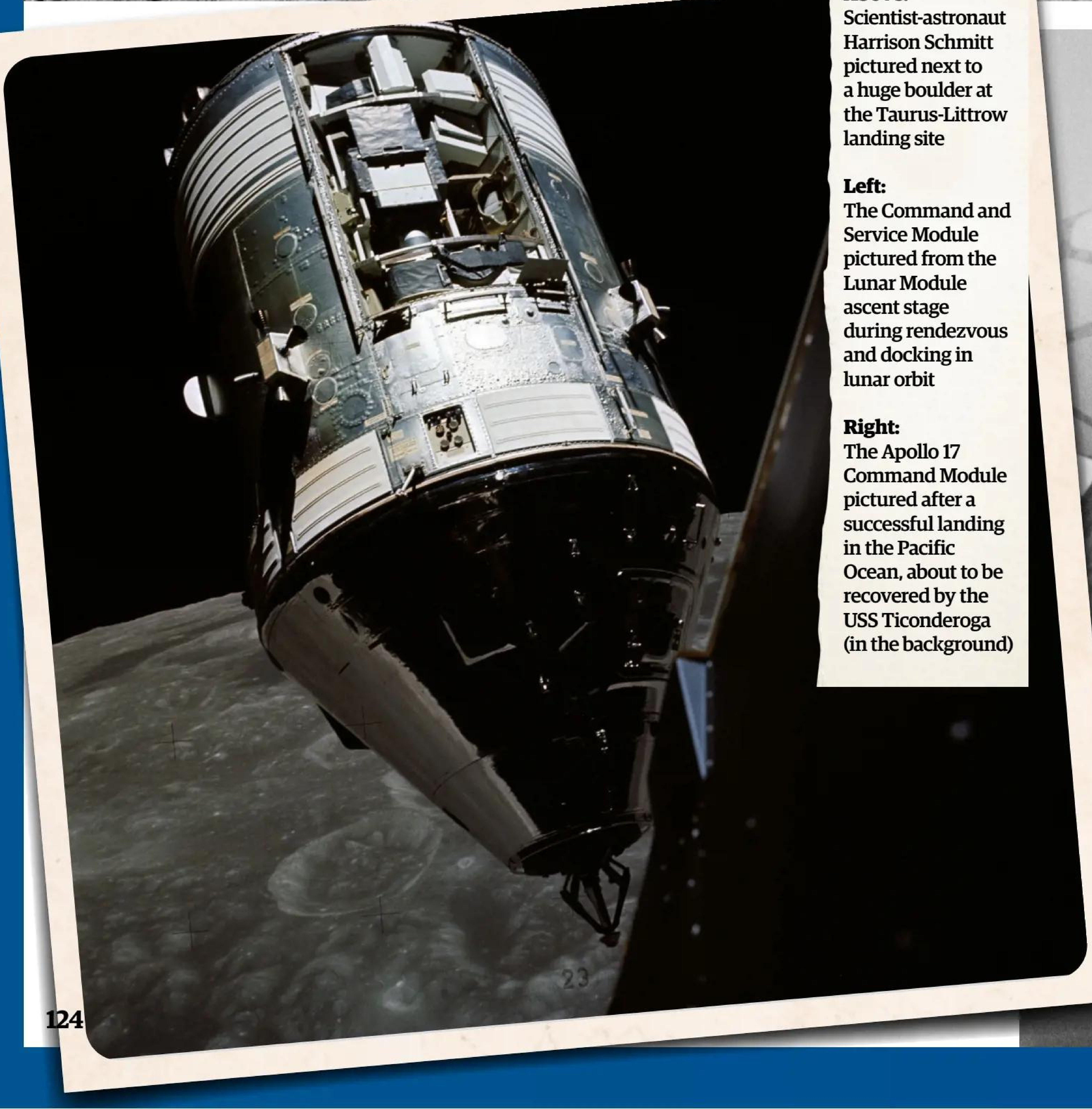
Right below: Ronald Evans pictured performing an EVA during the return trip to Earth, retrieving film cassettes from the lunar sounder, mapping camera and panoramic camera

Left: Apollo 17's Saturn V, illuminated on the launchpad at Kennedy Space Center

© NASA; JSC

“I'd just like to record that America's challenge of today has forged man's destiny of tomorrow... Godspeed, the crew of Apollo 17” **Commander Gene Cernan**





Above:
Scientist-astronaut Harrison Schmitt pictured next to a huge boulder at the Taurus-Littrow landing site

Left:
The Command and Service Module pictured from the Lunar Module ascent stage during rendezvous and docking in lunar orbit

Right:
The Apollo 17 Command Module pictured after a successful landing in the Pacific Ocean, about to be recovered by the USS Ticonderoga (in the background)

A minor technical error, due to a tank not being pressurised when expected, held up launch by almost three hours. But once the error was fixed, the crew lifted off on 7 December 1972. Cernan and Schmitt landed on the surface three days later without major incident, while Evans stayed in the Command Module.

Cernan's and Schmitt's first major challenge came when Cernan accidentally broke a wheel fender on their lunar rover. After that, abrasive Moon dust showered the astronauts as they drove around the surface. Cernan made a partial repair with some duct tape, joking he would like a 'mending award'. The next day, he and Schmitt taped some maps in place of the fender to better fix the problem.

The astronauts also deployed several scientific instruments, most notably a traverse gravimeter. The astronauts carried the instrument on the rover and took it out at several sites to measure the relative gravity, which gave scientists an idea about the lunar substructure.

In lunar orbit, Evans made observations of the surface and kept mission control entertained by joking about how much he stank because he had not taken a shower in several days.

Orange soil and a memorable ending

As Cernan and Schmitt worked near the rim of Shorty Crater on the second day, Schmitt exclaimed that he could see orange soil. In Cernan's autobiography, he said he feared Schmitt "has been up here too long and has overdosed on rocks." But when Cernan clambered over to take a look, he saw the orange soil, too. Later examination of samples of that soil taken back to Earth showed that the rocks were tiny spheres of coloured glass. These probably came from a volcanic vent.

After one more day racing the clock to do all the science they could, the lunar crew packed their gear and prepared to climb into Challenger for the last time. Alone on the surface, Cernan gave a short speech, concluding, "I'd just like to record that America's challenge of today has forged man's destiny of tomorrow. … Godspeed, the crew of Apollo 17."

Evans got a chance to do a quick spacewalk on the way back to Earth, retrieving some film canisters mounted outside the Command Module. The crew splashed down on 19 December in the South Pacific Ocean.

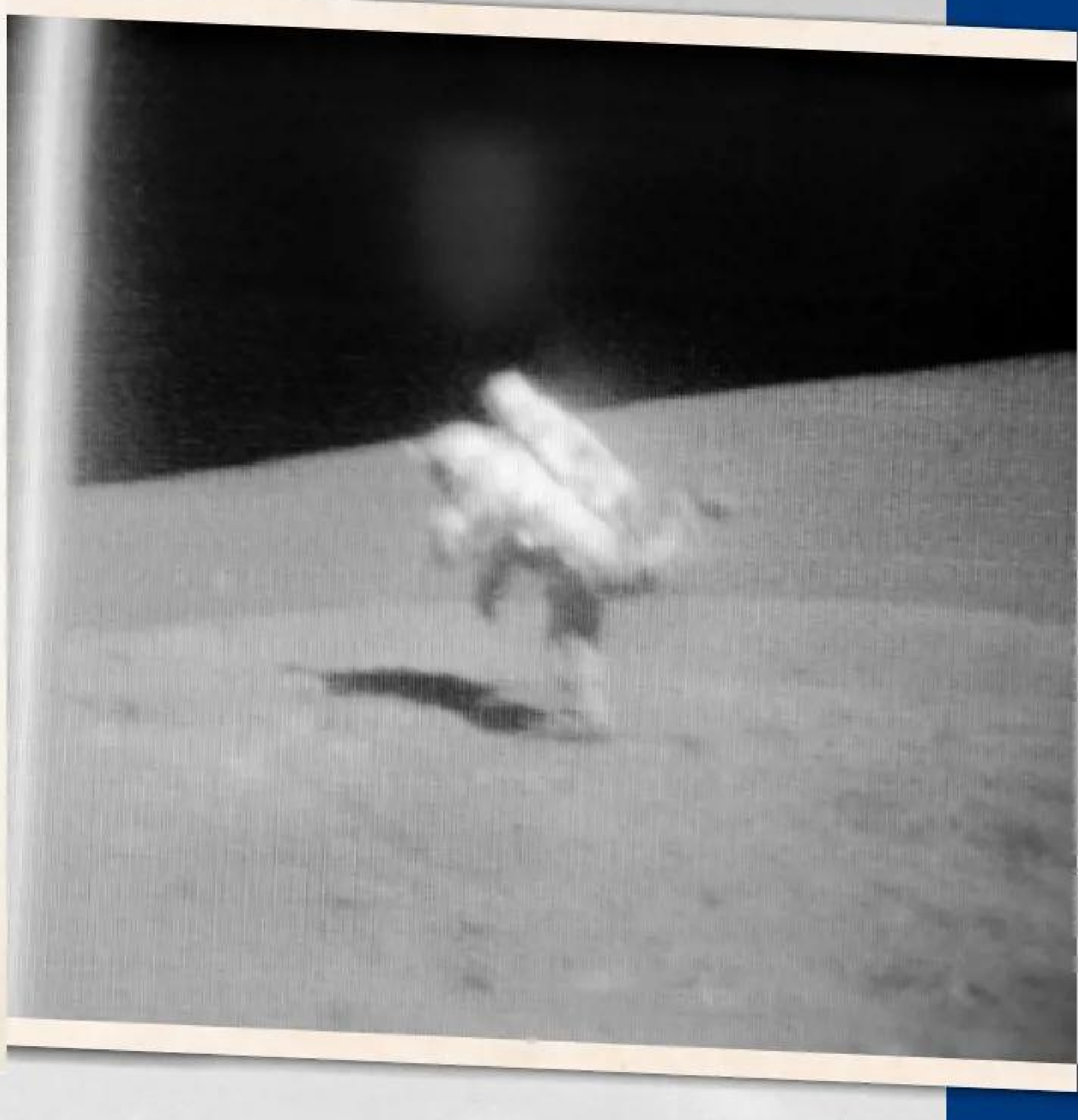
Apollo 17's astronauts spent a record 22 hours performing extravehicular activities on the Moon. The astronauts drove about 34 kilometers (21 miles) in the lunar rover and brought back 108 kilograms (238 pounds) of lunar rocks.

Apollo 17 legacy

The 50th anniversary of Apollo 17 is in December of 2022. The Command Module America is located at Space Center Houston near the NASA Johnson Space Center, while the upper stage of Lunar Module Challenger impacted the Moon as planned.

While this crew was the last one so far to have visited the Moon, NASA plans more lunar trips in the coming decade. The administration of President Donald Trump has directed the agency to send people to the Moon before going to Mars. First, NASA will test out its new Moon spacecraft, Orion, on a trip around the Moon without astronauts. The agency is also designing a Moon-orbiting space station.

While all of the people who visited the Moon so far were NASA astronauts, other entities could participate in the coming decades as well. One initiative announced in 2018, from private spaceflight company SpaceX, would send Japanese entrepreneur Yusaku Maezawa around the Moon with a group of artists. SpaceX says it will do this in 2023, using the company's Big Falcon Rocket to transport the space tourists there and back.



Top right: Harrison Schmitt, pictured in the Lunar Module prior to liftoff from the Moon

Right: Schmitt pictured here losing his balance and about to fall while bouncing across the lunar surface

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Remembering veteran astronaut Gene Cernan, in his own words

LAST MAN *on the* MOON

Reported by Mike Wall

Gene Cernan, the last human to walk on the Moon, passed away in January 2017 at the age of 82. The naval aviator joined NASA in 1963 and remained with the agency for over a decade, flying three times in space. He is one of only three people to travel to the Moon twice and one of only 12 people to walk upon its surface.

Cernan commanded NASA's Apollo 17 mission in December 1972, and he's the last person ever to leave footprints on the surface of the Moon. The former astronaut mused repeatedly about what his mission, and the Apollo programme in general, would mean to future generations.

"Just standing here, a little nostalgic, sort of gives me a chance to wonder whether this all happened in my life – whether it was reality or whether it was a dream," Cernan said in the 2014 documentary *Last Man on the Moon*, as he gazed at the Apollo 17 Command Module at NASA's Johnson Space Center in Houston.

"I also stand here, and I'm wondering what people are going to think, not in another 40 years, but maybe another 100 years – who knows, maybe another 1,000 years," he added.

"We did it way too early considering what we're doing now in space," Cernan added. In his 1999 autobiography *Last Man On The Moon*, Cernan wrote about the strange nature of the Apollo programme's timing. "President Kennedy reached far into the 21st century, grabbed a decade of time, and slipped it neatly into the 1960s and 1970s," he wrote. "Logic dictates that after Mercury and Gemini, we should have proceeded to build the shuttle, then an orbiting space station, and only then sought the Moon. It was as if our young nation had chosen to never again cross the Mississippi River after Lewis and Clark discovered the Northwest Passage."

More famous are the words Cernan uttered on the Moon more than four decades ago. For example, he and Apollo 17 crewmate Harrison Schmitt sang a variant of Ed Haley's *The Fountain in the Park* as they bounded across the lunar surface: "I was strolling on the Moon one day/In the merry, merry month of December."

And Cernan said the following just before climbing into the ascent stage of the Apollo 17 Lunar Module on 14 December 1972, to begin the journey home: "As I take man's last step from the surface back home for some time to come – but we believe not too long into the future – I'd like to just [say] what I believe history will record: that America's challenge of today has forged man's destiny of tomorrow. And, as we leave the Moon at [the valley] Taurus-Littrow, we leave as we came and, God willing, as we shall return, with peace and hope for all mankind. Godspeed, the crew of Apollo 17."

APOLLO
E. CERNAN
NASA

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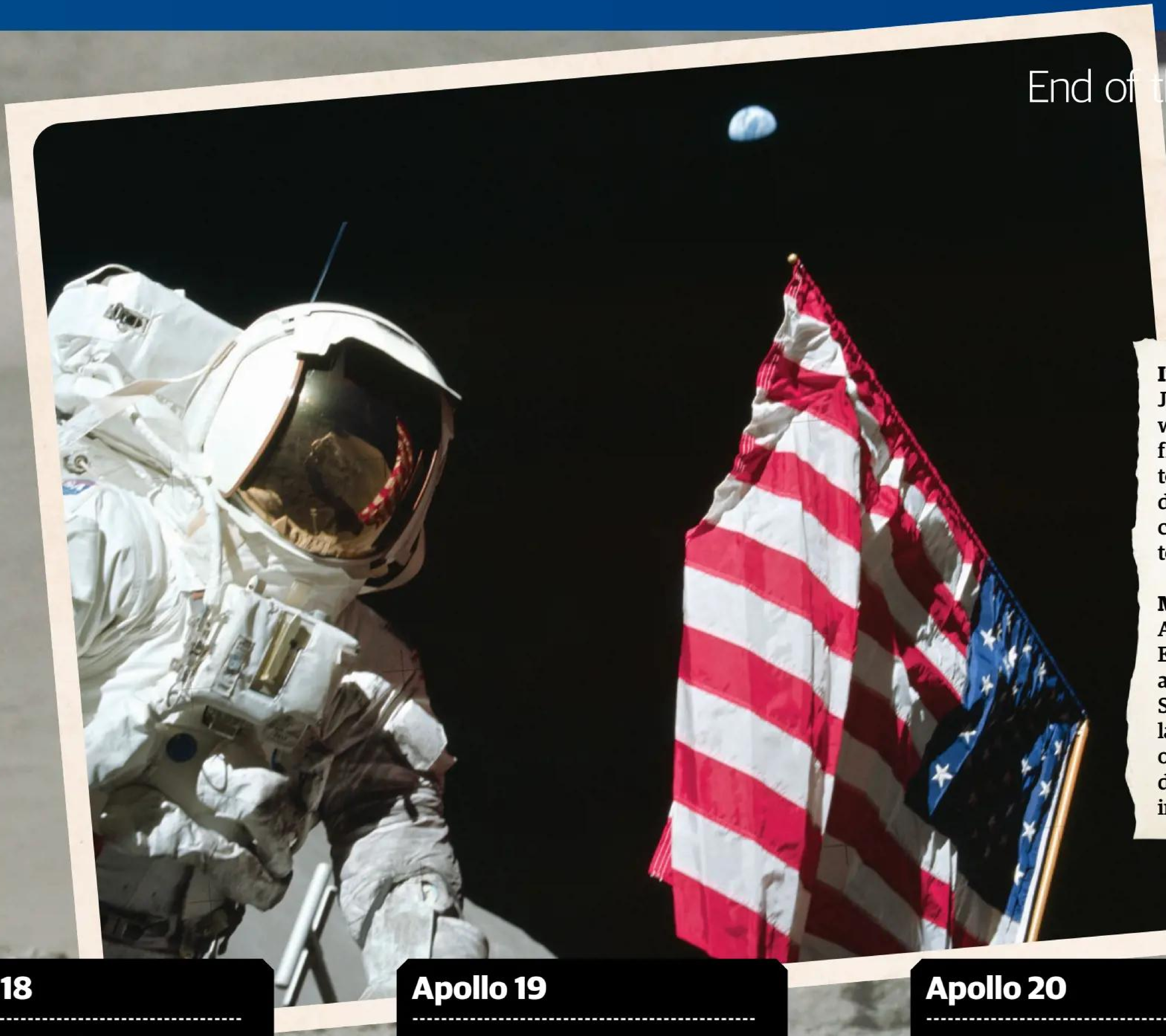
End of the APOLLO ERA

The cancellation of the last three Apollo missions abruptly ended the era of crewed lunar exploration, and scuppered efforts to go to Mars

Reported by Jonathan O'Callaghan

It's estimated that one-sixth of the world's population watched the historic Apollo 11 landing on the Moon in July 1969. But as the subsequent missions rolled by, interest quickly waned, and NASA's budget became stretched. With plans also in the works to build a space station in Earth orbit, called Skylab, the remaining three Apollo missions – 18, 19, and 20 – were scrapped.

The original Apollo plan had called for ten missions to the surface of the Moon in total. This would include landings across the lunar surface, and there were even some suggestions that a mission could go to the far side of the Moon. But in January 1970, NASA announced that Apollo 20 would be cancelled. Later that year, Apollo 18 and 19 were also dropped, while other missions were



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Inset: Jack Schmitt, with the US flag pointing towards Earth, during the final crewed mission to the Moon

Main: Astronauts Eugene Cernan and Jack Schmitt left the last footprints on the Moon during Apollo 17 in 1972

Apollo 18

DATE IT WAS DUE TO LAUNCH
February 1972

PROPOSED LUNAR LANDING SITE
Copernicus Crater

LIKELY CREW
Richard Gordon, Commander
Vance Brand, Command Module Pilot
Harrison Schmitt, Lunar Module Pilot

DATE CANCELLED
September 1970

Apollo 19

DATE IT WAS DUE TO LAUNCH
July 1972

PROPOSED LUNAR LANDING SITE
Hadley Rille

LIKELY CREW
Fred Haise, Commander
William Pogue, Command Module Pilot
Gerald Carr, Lunar Module Pilot

DATE CANCELLED
September 1970

Apollo 20

DATE IT WAS DUE TO LAUNCH
December 1972

PROPOSED LUNAR LANDING SITE
Tycho Crater

LIKELY CREW
Charles Conrad, Commander
Paul Weitz, Command Module Pilot
Jack Lousma, Lunar Module Pilot

DATE CANCELLED
January 1970

shuffled around. Apollo 16 and 17 even looked at risk too, but ultimately they were saved and became the final two missions, making Apollo 17 in December 1972 the last time humans have landed on the Moon to date. In total, six missions reached the surface of the Moon.

Each of the Apollo 18, 19 and 20 missions would likely have been a "J class" mission. These were three-day stays on the Moon that employed a lunar rover to cover large distances on the surface. But Jack Schmitt, who would become one of the last humans to set foot on the Moon on Apollo 17 after replacing astronaut Joe Engle, had wanted NASA to send one of these mission to the far side of the Moon, possibly a crater called Tsiolkovsky. Out of line of sight of Earth, this idea would have required some sort of satellite in lunar orbit to relay communications from the astronauts back to Earth, which was deemed too risky and costly.

One of the major reasons for scrapping the last three missions as a whole, which would have explored large impact craters such as Copernicus, Gassendi or Tycho on the Moon, was a diminished work force. While NASA employed 400,000 people in the 1960s, that had shrunk to 190,000 by January 1970, with 50,000 more jobs on the chopping block. Another issue was the aforementioned decline in interest, with NASA deciding the money that would be spent on the missions wouldn't be in the public interest.

The risk posed to the astronauts was also a concern. While Apollo 11 and 12 had gone relatively smoothly, Apollo 13 faced disaster in April 1970 when one of its oxygen tanks exploded on the way to the Moon. Only a daring return mission, which involved the crew slingshotting around the Moon and back to Earth, ensured that the three astronauts on board returned safely. Ultimately, it was decided that the continued risk of disaster of sending humans to the Moon was not worth the cost of what could be learned on the lunar surface.

There was the aforementioned issue of the Skylab space station, too. NASA wanted to maintain a permanent presence in space, and Skylab – which would see three different crews fly to the station while it was in orbit from 1973 to 1979 – was their plan for that. The station was essentially an empty shell of a Saturn V rocket that had been planned to take astronauts to the Moon, while each crew launched to the station upon Apollo spacecraft.

But it was money, ultimately, that was the downfall of the later Apollo missions. While NASA commanded more than four per cent of the national budget in the mid-1960s, this had dropped to less than two per cent by the early-1970s. With public interest waning, the case for continuing to spend billions of dollars on sending astronauts to the Moon looked shaky at best.

Had the later Apollo missions survived, however, our history of space exploration could have been very different. There were loose plans to use the Apollo missions as a precursor to a permanent lunar base, while the Saturn V rocket could have been used for a number of purposes, including missions to Mars. Instead, NASA decided to build Skylab in the 1970s and the Space Shuttle in the 1980s. By the 1990s, plans were put in place for the International Space Station (ISS), which continues to house astronauts in Earth orbit today. But who knows what might have been, had the Apollo programme not come to such an abrupt end.

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APOLLO MISSIONS

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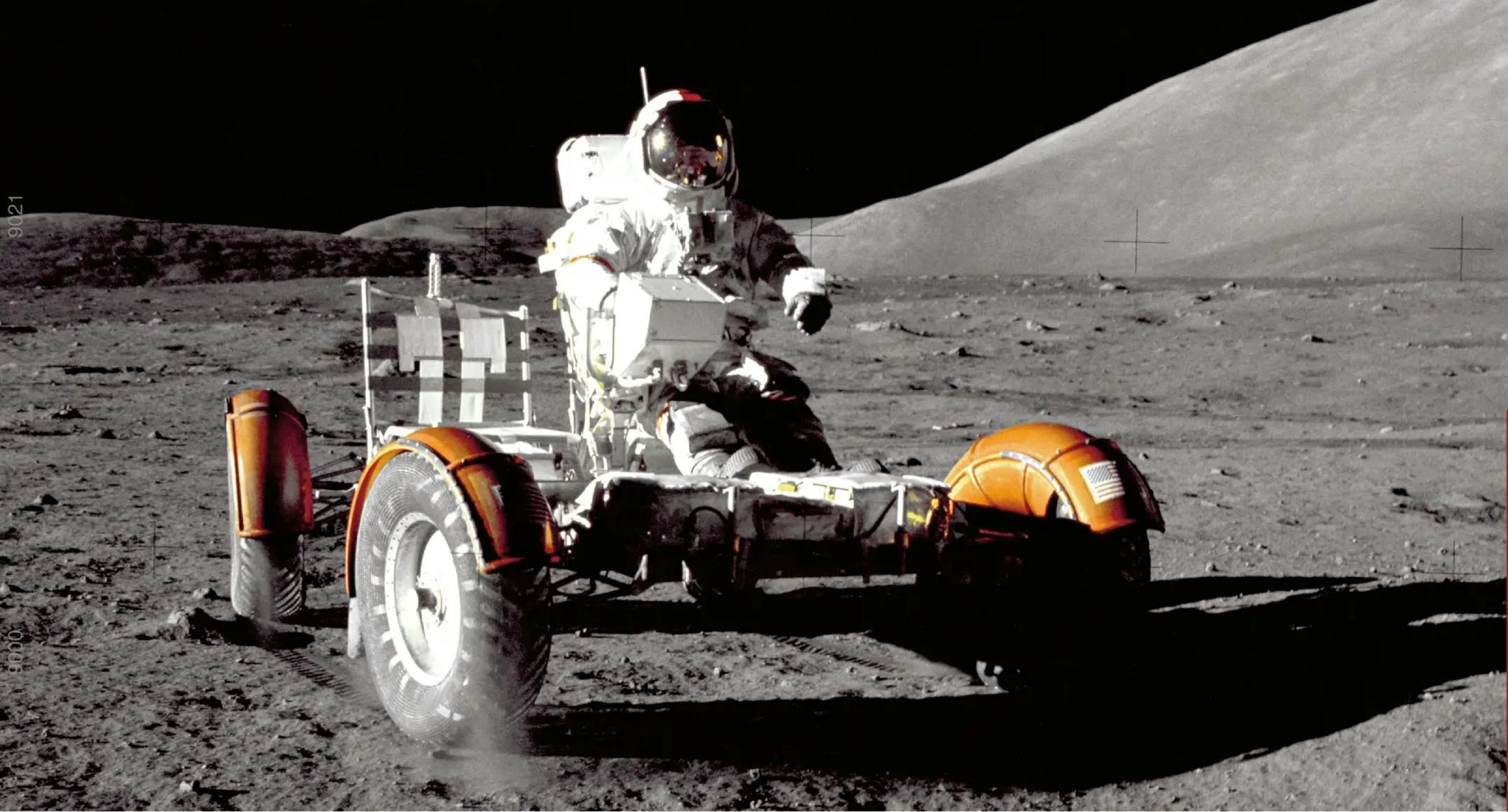

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